



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> :  C07K 1/04, 5/02		A1	(11) International Publication Number: WO 96/22304  (43) International Publication Date: 25 July 1996 (25.07.96)
<p>(21) International Application Number: PCT/US96/00786</p> <p>(22) International Filing Date: 19 January 1996 (19.01.96)</p> <p>(30) Priority Data: 08/375,904 20 January 1995 (20.01.95) US</p> <p>(71) Applicant: MOLECUMETICS, LTD. [US/US]; Suite 400, 2023 - 120th Avenue N.E., Bellevue, WA 98005-2189 (US).</p> <p>(72) Inventor: KAHN, Michael; 10916 80th Place N.E., Kirkland, WA 98034 (US).</p> <p>(74) Agents: HERMANNS, Karl, R. et al.; Seed and Berry L.L.P., 6300 Columbia Center, 701 Fifth Avenue, Seattle, WA 98104-7092 (US).</p>		<p>(81) Designated States: AL, AM, AU, AZ, BB, BG, BR, BY, CA, CN, CZ, EE, FI, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, RO, RU, SD, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AZ, BY, KG, KZ, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b></p> <p><i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	
<p>(54) Title: CONFORMATIONALLY CONSTRAINED REVERSE-TURN LIBRARY AND METHODS RELATING THERETO</p> <p>(57) Abstract</p> <p>Libraries of conformationally constrained-reverse turn mimetics, and methods of constructing the same are disclosed. The reverse-turn mimetics include beta-turn, gamma-turn and beta-bulge mimetics which mimic the biologically active conformation of a linear peptide. In a preferred embodiment, a template library is constructed based on the amino acid sequence of the linear peptide, and which contains a plurality of beta-turn, gamma-turn and beta-bulge mimetics of varying ring sizes. The template library is then screened in a suitable assay to identify a biologically active template library member. An optimized library is then constructed based on structure of the biologically active template member, and which includes substitutions to the amino acid sequence thereof. The optimized library is similarly screened to identify a biologically active reverse-turn mimetic. Methods relating to identifying library members which interact with biological targets of interest, and the use of such members as diagnostic, prophylactic and/or therapeutic agents are also disclosed.</p>			
<p style="text-align: center;"> <b>FMOC - FLKO - PAM</b>  <span style="margin-left: 100px;">○ Piperidine (deprotection)</span>  <span style="margin-left: 100px;">○ HATU / FMOC-Cl</span>  <span style="margin-left: 100px;">○ (Piperidine) deprotection</span>  <span style="margin-left: 100px;">○ TFA</span>  <span style="margin-left: 100px;">● NH<sub>2</sub></span>  <span style="margin-left: 100px;">○ NH<sub>2</sub> in isopropanol</span>  <span style="margin-left: 100px;">○ Cleavage from Resin</span>  <span style="margin-left: 100px;">10 (10) YOOLKO (004)</span> </p>			

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Description

## CONFORMATIONALLY CONSTRAINED REVERSE-TURN LIBRARY AND METHODS RELATING THERETO

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### Related Applications

This application is a continuation-in-part of U.S.S.N. 08/213,124, filed March 15, 1994; and a continuation-in-part of U.S.S.N. 08/236,674, filed May 2, 1994, which is a continuation of 07/926,350, filed August 6, 1992, which is a continuation-in-  
10 part of U.S.S.N. 07/651,800, filed February 7, 1991.

### Technical Field

This invention relates generally to libraries of conformationally constrained reverse-turn mimetics, methods relating to the identification of library members that interact with biological targets of interest, and the use of such members as diagnostic, prophylactic and/or therapeutic agents.  
15

### Background of the Invention

Random screening of molecules for possible activity as therapeutic agents has occurred for many years and resulted in a number of important drug discoveries.  
20 While advances in molecular biology and computational chemistry have led to increased interest in what has been termed "rational drug design", such techniques have not proven as fast or reliable as initially predicted. Thus, in recent years there has been a renewed interest and return to random drug screening. To this end, particular strides having been  
25 made in new technologies based on the development of combinatorial chemistry libraries, and the screening of such libraries in search for biologically active members.

In general, combinatorial chemistry libraries are simply a collection of molecules. Such libraries vary by the chemical species within the library, as well as the methods employed to both generate the library members and identify which members  
30 interact with biological targets of interest. While this field is still young, methods for generating and screening libraries have already become quite diverse and sophisticated. For example, a recent review of various combinatorial chemical libraries has identified a number of such techniques, including the use of both tagged and untagged library members (Janda, *Proc. Natl. Acad. Sci. USA* 91:10779-10785, 1994).

35 To date, combinatorial chemistry libraries have generally been limited to members of peptide or nucleotide origin. To this end, the techniques of Houghten et al.

illustrate an example of what is termed a "dual-defined iterative" method to assemble soluble combinatorial peptide libraries via split synthesis techniques (*Nature (London)* 354:84-86, 1991; *Biotechniques* 13:412-421, 1992; *Bioorg. Med. Chem. Lett.* 3:412, 1993). By this technique, soluble peptide libraries containing tens of millions of members have been obtained. Such libraries have been shown to be effective in identification of opioid peptides, such as methionine- and leucine-enkephalin (Doo and Houghton, *Life Sci.* 52, 1509-1517, 1993), and a N-acylated peptide library has been used to identify acetalins, which are potent opioid antagonists (Dooley et al., *Proc. Natl. Acad. Sci. USA* 90:10811-10815, 1993). More recently, an all D-amino acid opioid peptide library has been constructed and screened for analgesic activity against the mu ("μ") opioid receptor (Dooley et al., *Science* 266:2019-2022, 1994).

While combinatorial libraries containing members of peptide or nucleotide origin are of significant value, there is still a need in the art for libraries containing members of different origin. For example, traditional peptide libraries to large extent merely vary the amino acid sequence to generate library members, and do not impart a constrained secondary structure to such peptide members. It is well recognized that the secondary structures of peptides are important to biological activity. Thus, there is a need in the art for libraries containing members which mimic the active structure of biologically active peptides. There is also a need in the art for methods generating such libraries, as well as techniques for screening the library members against targets of interest, particularly biological targets, to identify bioactive library members. The present invention fulfills these needs, and provides further related advantages.

#### Summary of Invention

Briefly stated, the present invention is directed to libraries of conformationally constrained reverse-turn mimetics and methods relating to their generation thereof. This invention is further directed to methods relating to the screening and identification of library members that interact with biological targets of interest, as well as the use of such identified members as diagnostic, prophylactic and/or therapeutic agents.

In one embodiment of this invention, a library containing a plurality of conformationally-constrained reverse-turn mimetics as members is disclosed, the structures of which are set forth in greater detail in the following detailed description. In a related aspect, a method for identifying biologically active agents is disclosed comprising screening the above library members in a suitable assay, and thereby identifying biologically active library members.

In a further embodiment, there is disclosed a method for identifying a biologically active conformationally constrained reverse-turn mimetic which mimics a biologically active conformation of a linear peptide having a known amino acid sequence. In this method, conformationally constrained reverse-turn mimetics are constructed based on the known amino acid sequence of the linear peptide to yield a template library containing a plurality of members selected from conformationally constrained beta-turn, gamma-turn and beta-bulge mimetics having multiple ring sizes. The template library members are then screened in a suitable assay to identify a biologically active member of the template library. Next, conformationally constrained reverse-turn mimetics are constructed based on the biologically active member of the template library to yield an optimized library containing a plurality of members having varying amino acid substitutions based on the known amino acid sequence of the biologically active linear peptide. Lastly, the optimized library members are screened in a suitable assay to identify a biologically active member of the optimized library.

In yet a further embodiment, conformationally constrained reverse-turn mimetics are disclosed which are useful as diagnostic, prophylactic and/or therapeutic agents. The structure of such mimetics, as well as methods to synthesis the same, are disclosed in greater detail in the following detailed description.

Other aspects of this invention will become apparent upon reference to the following detailed description.

#### Brief Description of the Drawings

Figures 1A-1B illustrate a representative synthesis of conformationally constrained beta-turn mimetics having 12- and 14-membered rings.

Figures 2A-2C illustrate a representative synthesis of a conformationally constrained beta-turn mimetic having a 10-membered ring, as well as a gamma-turn mimetic having a 7-membered ring.

#### Detailed Description of the Invention

The present invention is generally directed to libraries containing conformationally constrained reverse-turn mimetics of naturally occurring or synthetic peptides (referred to herein as "reverse-turn mimetics" or "mimetics"), and which are useful in the identification of bioactive agents, such as diagnostic, prophylactic and/or therapeutic agents. In the practice of the present invention, the libraries may contain from tens to hundreds to even millions of individual reverse-turn mimetics (also referred to herein as "members").

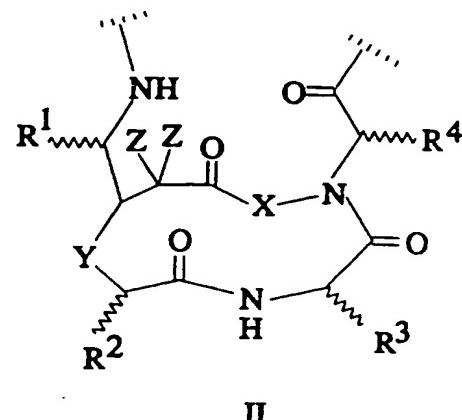
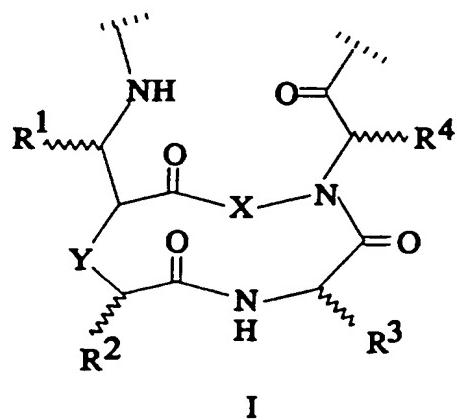
- Once assembled, the libraries of the present invention may be screened to identify individual members having bioactivity. Such screening of the libraries for bioactive members may involve, for example, evaluating the binding activity of members of the library or evaluating the effect the library members have on a functional assay.
- Screening is normally accomplished by contacting the library members (or subset of library members) with a target of interest, such as, for example, an antibody, enzyme, receptor or cell line. Library members which are capable of interacting with the target of interest are referred to herein as "bioactive library members" or "bioactive mimetics". For example, a bioactive mimetic may be a library member which is capable of binding to an antibody or receptor, which is capable of inhibiting an enzyme, or which is capable of eliciting or antagonizing a functional response associated, for example, with a cell line. In other words, the screening of the libraries of the present invention determines which library members are capable of interacting with one or more biological targets of interest. Furthermore, when interaction does occur, the bioactive mimetic(s) may then be identified from the library members. The identification of a single (or limited number) of bioactive mimetic(s) from the library yields reverse-turn mimetics which are themselves biologically active, and thus useful as diagnostic, prophylactic therapeutic agents, and may further be used to significantly advance identification of key compounds in these fields.
- The steps which are undertaken to identify a bioactive mimetic from a library depends primarily on whether the library is spatially or nonspatially addressable. While either library type is permitted in the practice of this invention, spatially addressable libraries are preferred. In a spatially addressable library, each reaction vessel in which an assay is performed contains a single mimetic or a small number of mimetics. Thus, in a spatially addressable library, when a bioactive mimetic is identified in a screening assay, its identity is specifically known, or known to be of a limited number of mimetics. In general, the size of spatially addressable libraries are limited by the required degree of spatial resolution. However, significant advances have recently been made which permit a relatively large number of members within a spatially addressable library.
- For example, photolithographic techniques now allow for the spatial resolution of a relatively large number of members (on the order of 64,000) in a small area, such as, a  $1.5 \text{ cm}^2$  chip. (Fodor et al., *Science* 251:717-723, 1991; Cho et al., *Science* 261:1300-1305, 1993) (both of which are incorporated by reference herein). Such techniques are known to those skilled in the art and summarized in Janda, *Proc. Natl. Acad. Sci. U.S.A.* 91:10779-10785, 1993 (incorporated herein by reference). Large, spatially addressable

libraries may also be constructed using an iterative approach, as disclosed by, for example, Houghten et al. (*Nature* 354:84-86, 1991) (incorporated herein by reference).

Alternatively, nonspatially addressable libraries can be made by constructing an encoded library as disclosed by Ohlemeyer et al. (*Proc. Natl. Acad. Sci. USA* 90:10922-10926, 1993) and Brenner et al. (*Proc. Natl. Acad. Sci. USA* 89:5181-5183, 1992) (both of which are incorporated herein by reference). In short, a nonspatially addressable library requires the ability to directly sequence the minute quantity of product that is associated with a polymer bead in the synthesis. This is readily achievable at the 5-10 picomolar range with peptide sequencing. Alternative, a nonsequenceable number can be cosynthesized with a coding sequenceable partner (e.g., peptide or oligonucleotide) which can be directly sequenced, or PCRed and sequenced. Small sequenceable coding strands can be made which can be sequenced using mass spectroscopy (see, e.g., Ohlemeyer et al., Nikolaiev et al., *Peptide Res.* 6:161-170, 1993) (incorporated herein by reference).

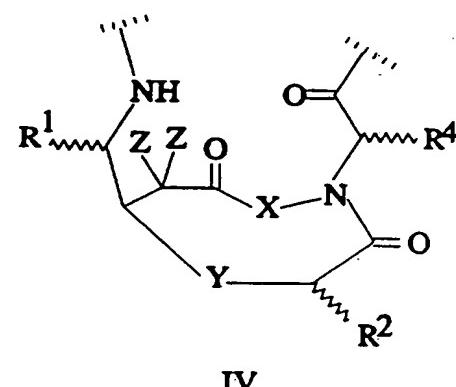
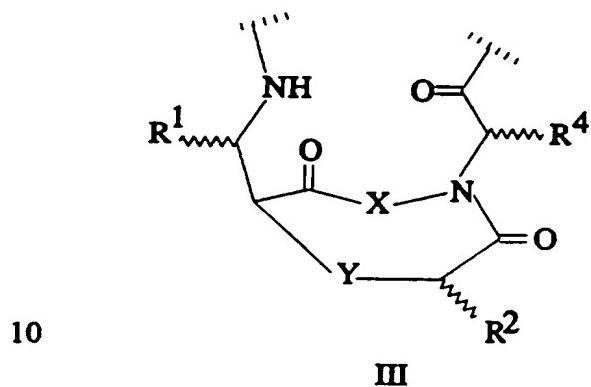
In one aspect of this invention, methods for the synthesis of library members are disclosed. As mentioned above, the mimetics of the present invention comprise conformationally constrained reverse-turn mimetics and, more specifically, encompass compounds of related structures, including mimetics of beta-turns ( $\beta$ -turns), gamma turns ( $\gamma$ -turns), and beta-bulges ( $\beta$ -bulges). In general, beta-turns are reversals in the direction of a polypeptide chain wherein the oxygen of the CO group of amino acid  $n$  is hydrogen bonded to the hydrogen of the NH group of amino acid  $n+3$ . Similarly, gamma-turns and beta-bulges are reversals in a polypeptide chain where the oxygen of the CO group of amino acid  $n$  is hydrogen bonded to the hydrogen of the NH group of amino acid  $n+2$  and  $n+4$ , respectively. The conformationally constrained reverse-turns of this invention "mimic" the three-dimensional structure of beta-turns, gamma-turns and beta-bulges, and thus serve as surrogates for such reverse-turn structures present in naturally-occurring proteins and/or peptides.

More specifically, a conformationally constrained beta-turn mimetic of this invention has the following structure I or II:



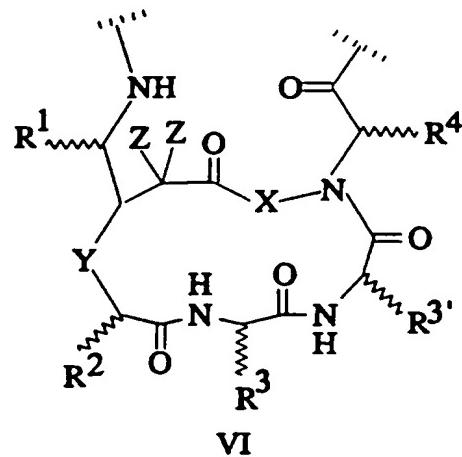
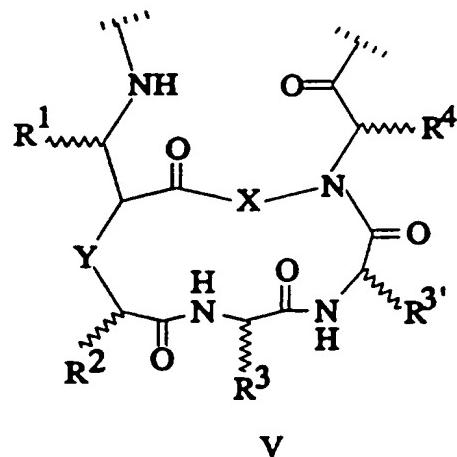
wherein  $R^1$ ,  $R^2$ ,  $R^3$  and  $R^4$  are amino acid side chain moieties or derivatives thereof,  
5 is selected from the chemical moieties identified in Table 1,  $Y$  is selected from  $-CH_2-$   
 $-N(Z)-$ ,  $-O-$  and  $-S-$ , and  $Z$  is  $-H$  or  $-CH_3$ .

A conformationally constrained gamma-turn mimetic of this invention has  
the following structure III or IV:



wherein  $R^1$ ,  $R^2$  and  $R^4$  are amino acid side chain moieties or derivatives thereof,  $X$  is selected from the chemical moieties identified in Table 1,  $Y$  is selected from  $-CH_2-$   
15  $-N(Z)-$ ,  $-O-$  and  $-S-$ , and  $Z$  is  $-H$  or  $-CH_3$ .

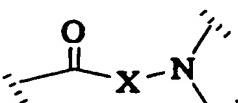
A conformationally constrained beta-bulge mimetic of this invention has  
the following structure V or VI:



wherein  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^{3'}$  and  $R^4$  are amino acid side chain moieties or derivatives thereof,  $X$  is selected from the chemical moieties identified in Table 1,  $Y$  is selected from  $-CH_2-$ ,  $-N(Z)-$ ,  $-O-$ , and  $-S-$ , and  $Z$  is  $-H$  or  $-CH_3$ .

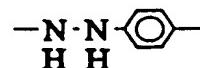
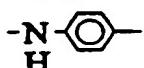
Table 1  
"X" Moieties of Structures I through VI

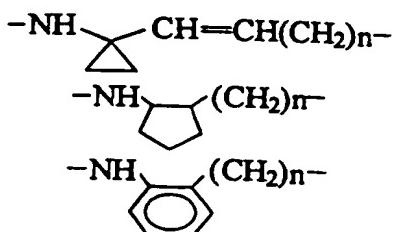
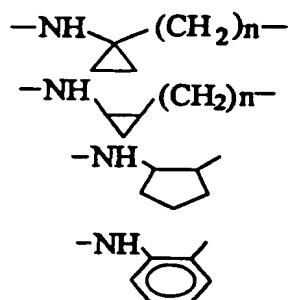
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where  $X =$

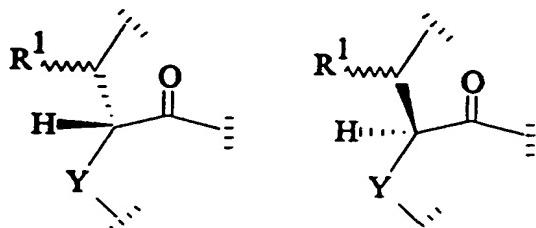
- |   |  |
|---|--|
| $-NH-$<br>$-NHC(Z)_2CH_2CH_2CH_2-$<br>$-NH(CH_2)_n-$<br>$-NH(CH_2)_nCH=CH-$<br>$-NHC(Z)_2(CH_2)_nNH-$<br>$-NHC(Z)_2CH=CH(CH_2)_n-$<br>$-NHC(Z)_2CH=C(Z)(CH_2)_n-$<br>$-NHNHC(Z)_2CH=CH(CH_2)_n-$<br>$-NHC(Z)_2(CH_2)_nCH=C=N-$<br>$-NHC(Z)_2(CH_2)_nC=CCH=N-$<br>$-NHC(Z)_2(CH_2)_nCH=CHCONH-$<br>$-NHC(Z)_2(CH_2)_nCH=CHCH_2NH-$ | $-NHC(Z)_2CH_2-$<br>$-NHC(Z)_2CH=CHCH_2-$<br>$-NHC(Z)_2(CH_2)_n-$<br>$-NH(CH_2)_nC\equiv C-$<br>$-NHNHC(Z)_2(CH_2)_n-$<br>$-NHC(Z)_2C\equiv C(CH_2)_n-$<br>$-NHC(Z)_2CH=CH(CH_2)_nNH-$<br>$-NHC(Z)_2(CH_2)_nCH=N-$<br>$-NHC(Z)_2(CH_2)_nCH=CHCH=N-$<br>$-NHC(Z)_2(CH_2)_nCONH-$<br>$-NHC(Z)_2(CH_2)_nC\equiv CCONH-$ |
|---|--|





(where  $n=1-4$  and  $Z = H$  or  $CH_3$ )

As used herein, the designation "  $\text{--- R}$ " indicates that the amino acid side chain moiety (or derivative thereof) may lie either above or below the plane of page. In the case of naturally occurring amino acids (i.e., "L-amino acids"), the R amino acid side chain moieties would lie below the plane of the page in structures I through VI above (i.e., "  $\text{--- R}$ "). However, if one or more D-amino acids were employed, corresponding R amino acid side chain moiety would lie above the plane of the page in the above structures (i.e., "  $\text{--- R}$ "). In a preferred embodiment, L-amino acids are employed to more closely mimic the structure of native protein. The designation "  $\text{--- } \dots \text{---}$ " indicates the remainder of the molecule. In other words, additional chemical moieties are covalently attached to the terminal carbonyl and amine groups of structures I through VI above. This aspect of the invention is addressed in greater detail below. Moreover, it should be understood that the chiral carbon immediately adjacent to the carbon atom having the amino acid side chain moiety  $R^1$  of structures I through VI must be in either the  $\alpha$ - or  $\beta$ -position. In other words, this carbon atom may have either the following structures:

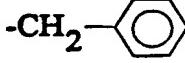
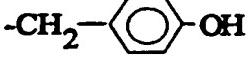
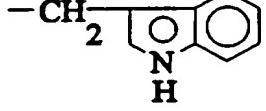
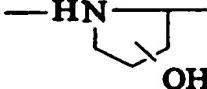


As used herein, the term "an amino acid side chain moiety" represents an amino acid side chain moiety present in naturally occurring proteins, including (but not limited to) the naturally occurring amino acid side chain moieties identified in Table I. Other naturally occurring amino acid side chain moieties of this invention include (but are not limited to) the side chain moieties of 3,5-dibromotyrosine, 3,5-diiodotyrosine,

hydroxylysine,  $\gamma$ -carboxyglutamate, phosphotyrosine and phosphoserine. In addition, glycosylated amino acid side chains may also be used in the practice of this invention, including (but not limited to) glycosylated threonine, serine and asparagine.

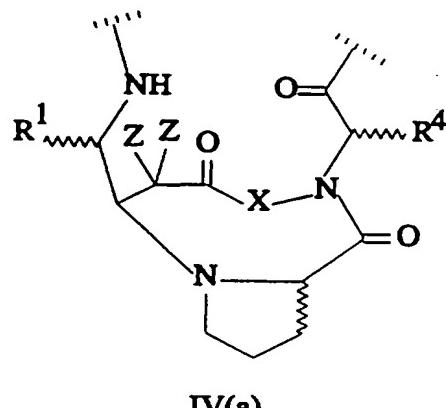
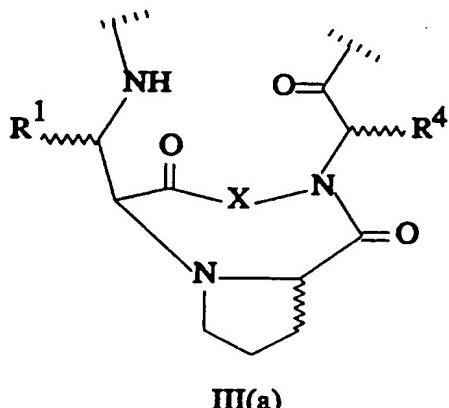
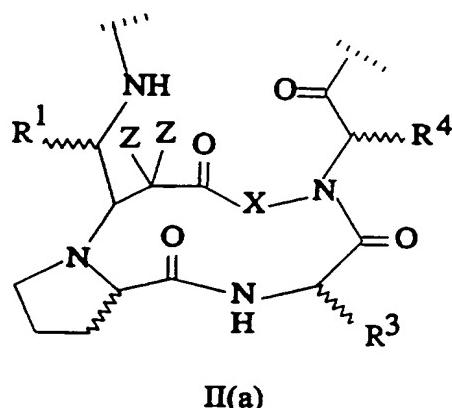
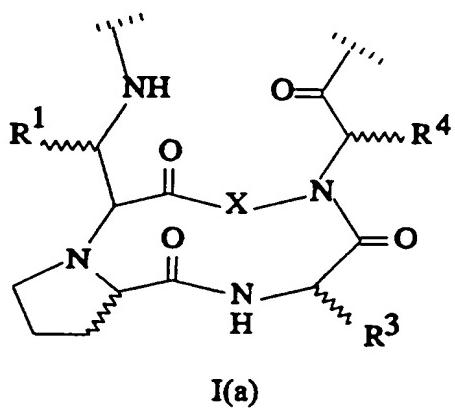
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Table 2  
Amino Acid Side Chain Moieties

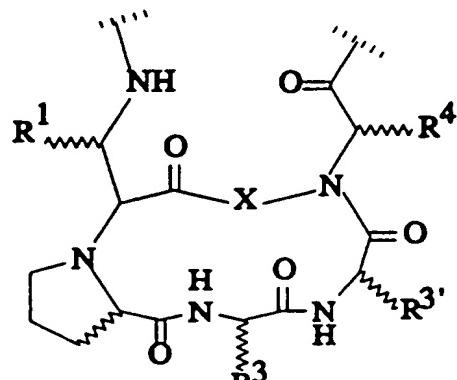
<u>Amino Acid Side Chain Moity</u>	<u>Amino Acid</u>
-H	Glycine
-CH <sub>3</sub>	Alanine
-CH(CH <sub>3</sub> ) <sub>2</sub>	Valine
-CH <sub>2</sub> CH(CH <sub>3</sub> ) <sub>2</sub>	Leucine
-CH(CH <sub>3</sub> )CH <sub>2</sub> CH <sub>3</sub>	Isoleucine
-(CH <sub>2</sub> ) <sub>4</sub> NH <sub>3</sub> <sup>+</sup>	Lysine
-(CH <sub>2</sub> ) <sub>3</sub> NHC(NH <sub>2</sub> )NH <sub>2</sub> <sup>+</sup>	Arginine
	Histidine
-CH <sub>2</sub> COO <sup>-</sup>	Aspartic acid
-CH <sub>2</sub> CH <sub>2</sub> COO <sup>-</sup>	Glutamic acid
-CH <sub>2</sub> CONH <sub>2</sub>	Asparagine
-CH <sub>2</sub> CH <sub>2</sub> CONH <sub>2</sub>	Glutamine
	Phenylalanine
	Tyrosine
	Tryptophan
-CH <sub>2</sub> SH	Cysteine
-CH <sub>2</sub> CH <sub>2</sub> SCH <sub>3</sub>	Methionine
-CH <sub>2</sub> OH	Serine
-CH(OH)CH <sub>3</sub>	Threonine
	Proline
	Hydroxyproline

When the amino acid side chain moiety of structures I through VI contains proline, the five-membered pyrrolidine ring may be a component of the conformationally constrained reverse-turn mimetic. In other words, proline may be present at any location within the conformationally constrained reverse-turn mimetic in place of one or more "-NH-CH(R)-" moieties. For example, inclusion of proline in structures I through VI above at the "-Y-CH(R<sup>2</sup>)-" position (where Y = N) yields the following structures I through VI(a):

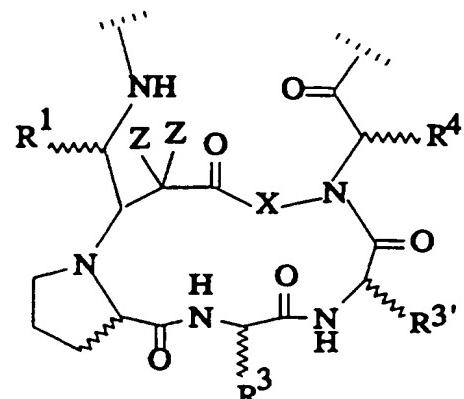
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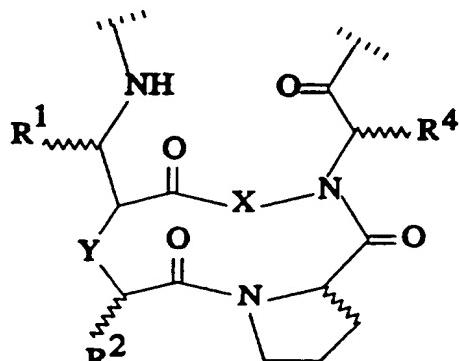
V(a)



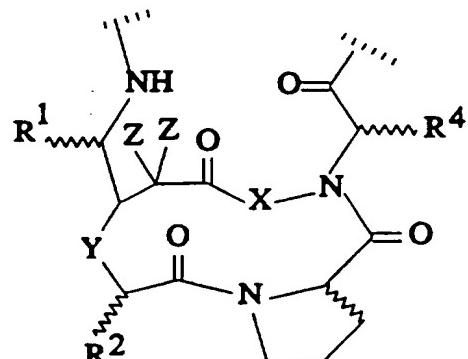
VI(a)

where R<sup>1</sup>, R<sup>3</sup>, R<sup>3'</sup>, R<sup>4</sup>, X and Z are as identified above with regard to structures I through VI.

Alternatively, structures I and II may be modified by inclusion of proline within the conformationally constrained reverse-turn mimetic at the "-NH-CH(R<sup>3</sup>)-" position, yielding structures I(b) and II(b) below:



I(b)

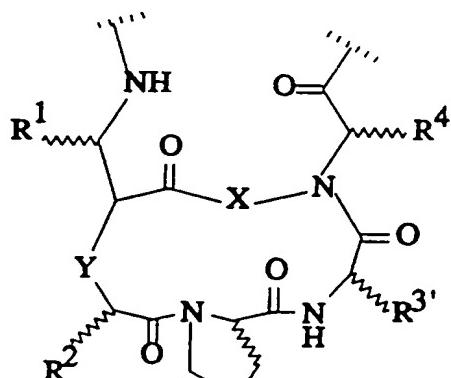


II(b)

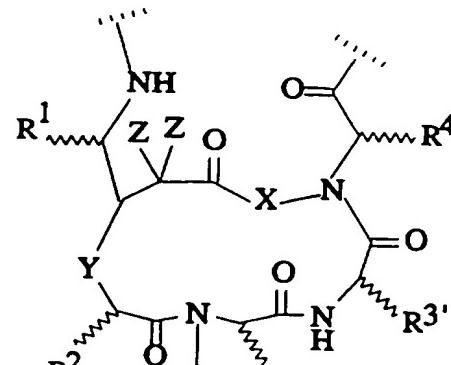
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Similarly, structures V and VI may be modified by inclusion of proline within the conformationally constrained reverse-turn mimetic at the "-NH-CH(R<sup>3</sup>)-" or "-NH-CH(R<sup>3'</sup>)-" positions, yielding structures V(b), VI(b), V(c) and VI(c):

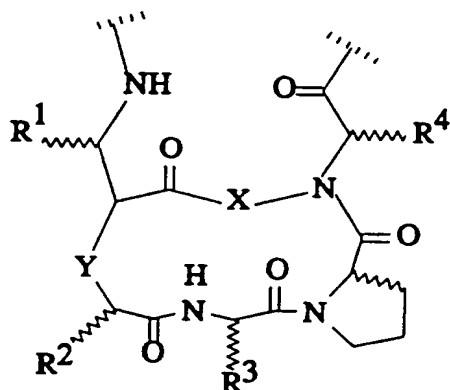
15



V(b)

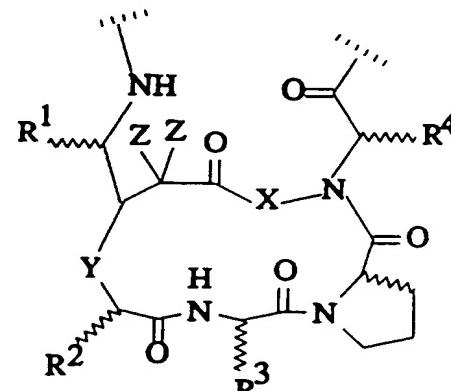


VI(b)



5

V(c)



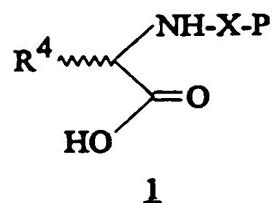
VI(c)

where R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>3'</sup>, R<sup>4</sup>, X, Y and Z are as identified above with regard to structures I through VI.

Accordingly, general structures I through VI above include structures I(a), II(a), III(a), IV(a), V(a), VI(a), I(b), II(b), V(b), VI(b), V(c) and VI(c) representative examples where the amino acid side chain moiety is proline (or derivative thereof).

The conformationally constrained reverse-turn mimetics of the present invention are made by utilizing appropriate starting component molecules (hereinafter referred to as "component pieces"). In short, first, second and third component pieces are combined (in various combinations) and then cyclized to yield the conformationally constrained reverse-turn mimetics of this invention.

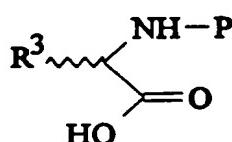
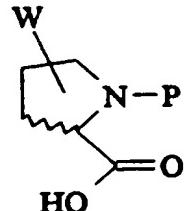
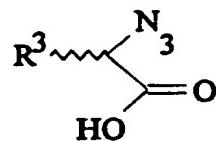
Within the context of this invention, a "first component piece" has the following structure 1:



5 wherein R<sup>4</sup> is an amino acid side chain moiety or derivative thereof, X is selected from the chemical moieties identified in Table 1, and P is a protective group suitable for use in peptide synthesis.

A "second component piece" of this invention is selected from the following structures 2(a), 2(b) and 2(c):

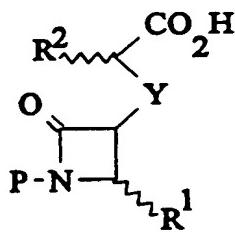
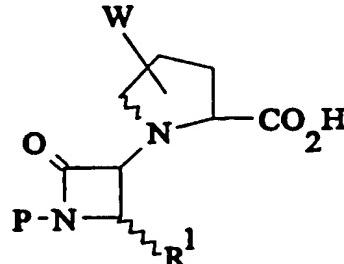
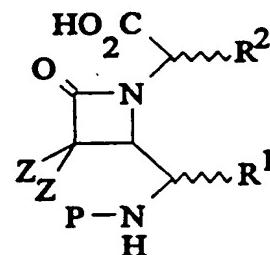
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2(a)2(b)2(c)

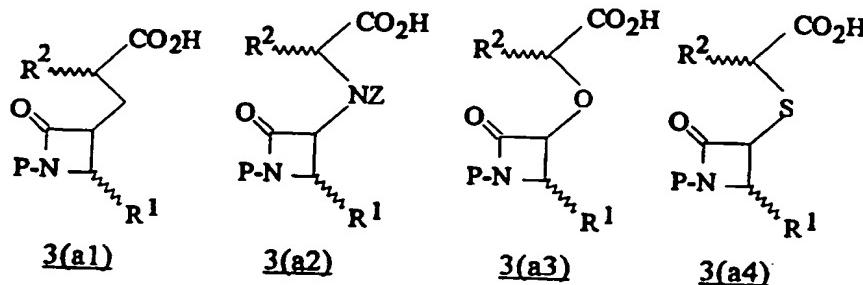
15 wherein R<sup>3</sup> is an amino acid side chain moiety or derivative thereof, W is -H, -OH alkyl, aryl, -O-alkyl, -O-aryl, -S-alkyl or -S-aryl, and P is a protective group suitable for use in peptide synthesis.

A "third component piece" of this invention is selected from the following structures 3(a), 3(b) and 3(c):

20

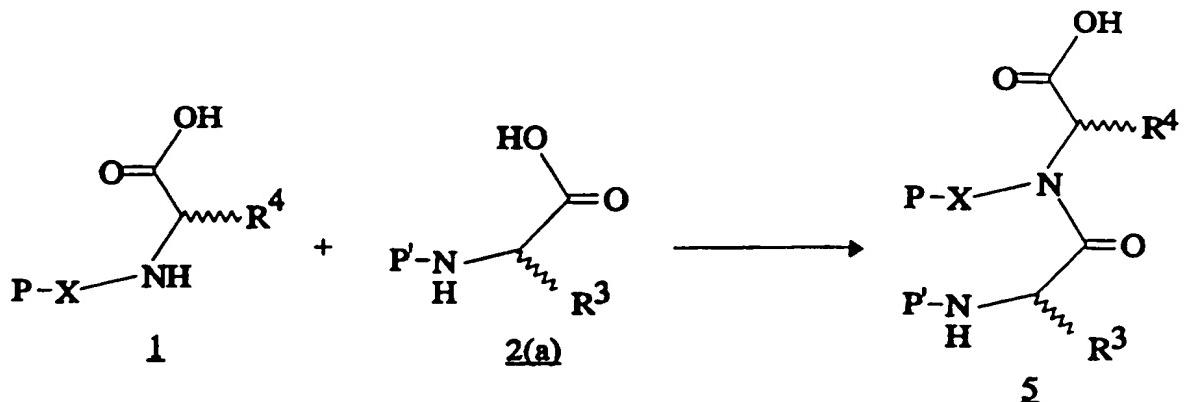
3(a)3(b)3(c)

where R<sup>1</sup> and R<sup>2</sup> are amino acid side chain moieties or derivatives thereof, Y is -CH-NZ-, -O- or -S-, Z is H or methyl, W is -H, -OH, alkyl, aryl, -O-alkyl, -O-aryl, -S-alkyl or -S-aryl, and P is a protective group suitable for use in peptide synthesis. Thus, w/t Y of structure 3(a) is -CH<sub>2</sub>-, -NZ-, -O- or -S-, the following third modular component pieces 3(a1), 3(a2), 3(a3) and 3(a4), respectively, are obtained:

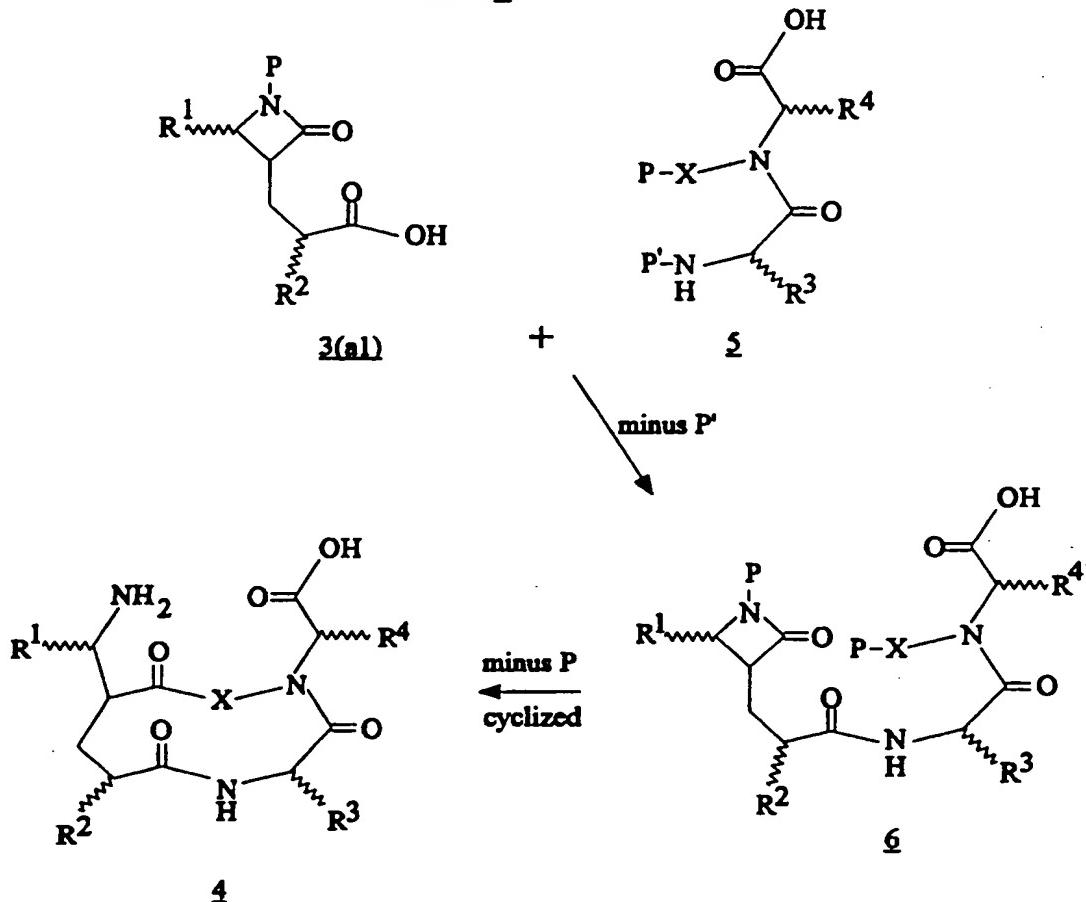


More specifically, conformationally constrained beta-turn mimetics of the invention (see structures I and II above) are synthesized by reacting a first component piece with a second component piece to yield a combined first-second intermediate followed by reacting the first-second intermediate with a third component piece to yield a combined first-second-third intermediate, and then cyclizing the resulting first-second-third intermediate to yield the conformationally constrained beta-turn mimetic. Conformationally constrained gamma-turn mimetics (see structures III and IV above) are synthesized in the same manner, except that the second component piece is omitted (i.e., a first-third intermediate is cyclized). Similarly, conformationally constrained beta bulges (see structures V and VI above) are synthesized by use of two second component pieces (i.e., a first-second-second-third intermediate is cyclized).

For example, the general synthesis of a conformationally constrained beta-turn mimetic having structure 4 below may be synthesized by the following technique. A first modular component piece 1 is combined with a second modular component piece 2(a) to yield a first-second intermediate 5 as illustrated below (it should be recognized that following reaction scheme is presented for illustration purposes, and that the carboxylic acid moiety of structure 1 should be suitably protected by, for example, esterification, by formation of an amide bond, or by attachment to a solid support):



A third modular component piece 3(a1) is then combined with the first-second intermediate 5 to give a pre-cyclized beta-turn mimetic 6, which in turn is cyclized to yield the beta-turn mimetic of structure 4:



All conformationally constrained reverse-turn mimetics of this invention may be synthesized by appropriate choice of the various component pieces by the general procedure outlined above. For example, R group variations to structures I

through VI may be made by use of appropriate first, second and third component pieces possessing the desired R group. Similarly, conformationally constrained gamma-1 mimetics may be synthesized by linking a first component piece with a third component piece (omitting the second component piece), followed by cyclization. Alternatively, 5 first component piece may be combined with a second component piece, followed by combination with yet another second component piece to yield a first-second-second intermediate. This intermediate may then be combined with a third component piece, cyclized to yield the corresponding conformationally constrained beta-bulge mimetic. Additional disclosure directed to the synthesis of the conformationally constrained reverse-turn mimetics of this invention is set forth in Examples 1-3 below.

Synthesis of the peptide mimetics of the library of the present invention may be accomplished using known peptide synthesis techniques, in combination with first, second and third component pieces of this invention. More specifically, any amino acid sequence may be added to the N-terminal and/or C-terminal of the conformationally constrained reverse-turn mimetic. To this end, the mimetics may be synthesized on solid support (such as PAM resin) by known techniques (see, e.g., John M. Stewart and Janis D. Young, *Solid Phase Peptide Synthesis*, 1984, Pierce Chemical Company, Rockford, Illinois).

In addition, a combination of both solution and solid phase synthesis techniques may be utilized to synthesize the peptide mimetics of this invention. For example, a solid support may be utilized to synthesize the linear peptide sequence up to the point that the conformationally constrained reverse-turn is added to the sequence. A suitable conformationally constrained reverse-turn mimetic which has been previously synthesized by solution synthesis techniques may then be added as the next "amino acid" to the solid phase synthesis (i.e., the conformationally constrained reverse-turn mimetic which has both an N-terminus and a C-terminus, may be utilized as the next amino acid to be added to the linear peptide). Upon incorporation of the conformationally constrained reverse-turn mimetic into the sequence, additional amino acids may then be added to complete the peptide vaccine bound to the solid support. Alternatively, the linear N-terminus and C-terminus protected peptide sequences may be synthesized on solid support, removed from the support, and then coupled to the conformationally constrained reverse-turn mimetic in solution using known solution coupling techniques.

In another aspect of this invention, methods for constructing the libraries are disclosed. Traditional combinatorial chemistry techniques (see, e.g., Gallop et al., *Med. Chem.* 37:1233-1251, 1994) permit a vast number of compounds to be rapidly prepared by the sequential combination of reagents to a basic molecular scaffold.

Combinatorial techniques have been used to construct peptide libraries derived from the naturally occurring amino acids. For example, by taking 20 mixtures of 20 suitably protected and different amino acids and coupling each with one of the 20 amino acids, a library of 400 (i.e.,  $20^2$ ) dipeptides is created. Repeating the procedure seven times 5 results in the preparation of a peptide library comprised of about 26 billion (i.e.,  $20^8$ ) octapeptides.

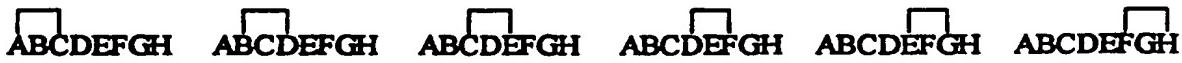
The peptide library described above results in a traditional combinatorial library derived from naturally occurring amino acids. Traditional combinatorial libraries consist of members differing only in the sequence in which its constituents are combined. For 10 example, a library of octapeptides consists of members including ABCDEFGH, ACBDEFGH, ABDCEFGH, etc., where A-H represent amino acids. In the practice of the present invention, the library is composed of conformationally constrained reverse-turn mimetics. That is, for any given peptide sequence, a multitude of reverse-turns are possible. Accordingly, the libraries of the present invention may be significantly larger 15 and more diverse than a library constructed solely by sequence variation of a linear peptide. Such reverse-turn mimetic libraries provide not only compounds of fixed sequence, but within each fixed sequence, provide a family of mimetics of various fixed conformations.

To illustrate this point, a representative library of reverse-turn mimetics for the 20 peptide ABCDEFGH are presented schematically below.

Beta-Turns:



25 Gamma-Turns:



Beta-Bulges:



30

The above library generally comprises 5 beta-turn mimetics, 6 gamma-turn mimetics and 4 beta-bulge mimetics. Moreover, for each one of the above representations, additional reverse-turn mimetics may be constructed. As disclosed above, the conformation of the reverse-turn mimetics are constrained by cyclizing the first and third component pieces

through covalent coupling of linking group X of the first component piece with carbonyl of the azetidinone group of the third component piece (see Example 3). The presence of additional component pieces between the first and third component pieces determines the nature of the reverse-turn mimetic: cyclization of first-second-third, five 5 third, and first-second-second-third component pieces yield beta-turn, gamma-turn, and beta-bulge mimetics, respectively. Accordingly, in addition to the multiplicity of reverse turns possible for a given sequence, variation of linking group X (see Table 1) provides even greater diversity of the mimetic library.

The libraries of the present invention thus differ from existing combinatorial 10 libraries of linear peptides. For example, in most hexapeptide libraries (i.e., ABCDE each position is randomized to afford libraries of  $10^6$  to  $10^7$  members (i.e., A(20)B(20)C(20)D(20)E(20)F(20) =  $6.4 \times 10^7$  members). Although it is conceptually possible to generate libraries of this type for reverse-turn mimetics, realistically it is unattractive for several reasons. First, the reverse-turn library is necessarily larger because 15 of the number of possible linker groups X and, therefore, there is a smaller amount of any one component in the library, thus making any single component harder to find (Medynski, *Biotechnology* 12:709-710, 1994). Second, a large number of unnatural building blocks need to be initially synthesized. Third, the libraries of this invention are not suitable for direct sequencing. Linear peptide libraries can be sequenced using 20 peptide microsequencing techniques, which can provide sequence information on as little as picomolar levels of material (see, e.g., Lam et al., *Nature* 354:82-84, 1992). However, in order for this technique to work, one must be able to cleave the individual amino acids in the peptide. The reverse turn mimetics of this invention do not have the capability within the conformationally constrained ring, which thus precludes this type 25 of sequencing.

Accordingly, in the practice of this invention, the libraries are based on a known linear peptide sequence as the starting point. The peptide sequence may be derived from a naturally occurring peptide or protein, or may be generated via a biopolymer library such as a synthetic peptide or phage display. Once the peptide sequence is chosen, the 30 libraries of the present invention are preferably constructed in two phases: (1) determination of the best template, and (2) optimization of the interaction of the side chains of the selected template. Both of these phases involve evaluation of the interaction of the individual library members with a particular biological target of interest as discussed below.

The determination of the best template entails evaluation of various possible reverse-turns for the particular sequence chosen. In other words, the first phase search

out the shape of the mimetic for presentation of the sequence information. By way of example, assuming a hexapeptide of the sequence ABCDEF as the peptide of interest, a library of the type shown below is first constructed.

5



The above represents a nested set of beta-turn, gamma-turn, and beta-bulge turn mimetics of different sizes and conformations based on the primary sequence ABCDEF. The above library consists of three beta-turns, with each turn containing a different linker group X. For example, if three different linker groups are used, beta-turn mimetics containing 10-, 12-, and 14-membered rings may be prepared (see Example 3). Similarly, the above library also consists of four gamma-turn mimetics, and by appropriate selection of X, gamma-turn mimetics containing 7-, 9-, and 11-membered rings may be prepared. The above library further consists of two beta-bulge mimetics which, using three different X linker groups, results in beta-bulge mimetics containing 13-, 15-, and 17-membered rings. With the above library thus constructed, the selection of the best template is performed by contacting the library members with the target of interest in a suitable assay. For example, the best template (as determined by the positive interactions or "hits" of the assay) may be a beta-turn containing a 12-membered ring such as shown below.



Once the best template is selected, the side chains of the template are then optimized. In the side chain optimization step, the template is maintained and the various residues (A through F) are randomized. The randomization involves the synthesis of additional compounds in which other side chains (other amino acid derived component pieces) are substituted. Both turn residues (C-F) and adjacent residues (A-B) may be randomized. The randomization may be carried out in a single screen, or alternatively, the randomization may be separated into two or more rounds of screening. As with template selection, the determination of the optimal side chains is achieved by screening using an appropriate assay. The results of the screening assay may provide a beta-turn containing a 12-membered ring with a sequence as shown below.

12  
A B G D H F

The preparation of a library by the above method is described in Example 4.

In a further aspect of this invention, methods for the screening the libraries 1  
5 bioactivity and isolating bioactive library members are disclosed. The libraries of t  
present invention may be screened for bioactivity by a variety of techniques a  
methods. Generally, the screening assay may be performed by (1) contacting a libra  
with a biological target of interest, such as a receptor, and allowing binding to occ  
between the mimetics of the library and the target, and (2) detecting the binding event 1  
10 an appropriate assay, such as by the colorimetric assay disclosed by Lam et al. (*Natu*  
*354*:82-84, 1991) or Griminski et al. (*Biotechnology*, *12*:1008-1011, 1994) (both  
which are incorporated herein by reference). In a preferred embodiment, the libra  
members are in solution and the target is immobilized on a solid phase. Alternativel  
the library may be immobilized on a solid phase and may be probed by contacting it wi  
15 the target in solution.

As discussed above, when the library of this invention is spatially addressable ar  
a positive interaction "hit" is achieved, the structure of the bioactive mimetic will 1  
known, or known to be of a limited number of structures. In the case of nonspatial  
addressable libraries of this invention, depending upon the particular embodiment of th  
screening bioassay, certain characteristics and properties may be imposed upon th  
reverse-turn mimetic to facilitate the recognition of bioactivity in a screening assay ar  
also to permit the isolation and identification of the mimetic. For example, a recepto  
bound bioactive mimetic may be collected through a binding interaction with a soli  
phase immobilized ligand-binding protein, such as avidin immobilized on a magneti  
bead. In such a screening assay, to effect binding of the receptor-bound mimetic to th  
immobilized ligand-binding protein, the mimetic need possess a suitable ligand. In th  
above mentioned example where the immobilized ligand binding protein is avidin, th  
mimetic ligand is preferably biotin.

In the above example, once the biotin of the receptor-bound mimetic has bee  
30 bound to the avidin immobilized on magnetic beads, the bioactive mimetic may be readil  
removed from the immobilized receptor by applying a magnetic field. For example  
contacting the magnetic beads with a magnet is effective in separating the mimetic fror  
the receptor. To identify the bioactive mimetic, the mimetic is then released from th  
magnetic solid phase by, for example, cleavage. Cleavage of the mimetic from th  
magnetic bead may occur through either chemical or enzymatic means. In either case

the mimetic should possess a suitable cleavable linkage. In a preferred embodiment, the mimetic is cleaved from the magnetic bead by enzymatic means and the cleavable linkage is a peptide sequence susceptible to enzymatic cleavage. For example, the enzyme thrombin effectively cleaves the sequence GRG (glycine-arginine-glycine). Accordingly, 5 thrombin treatment of a magnetically bead bound mimetic possessing a cleavable link GRG results in cleavage of the GRG sequence and release of the bioactive mimetic. Additional strategies for cleavable linkers are disclosed by Patek et al., *Int. J. Peptide Protein Res.* 42:97-117, 1993 (incorporated herein by reference).

The conformationally-constrained reverse-turn mimetics of the present 10 invention may thus incorporate a cleavable linker to facilitate release of a bioactive mimetic from the mimetic screening format prior to mimetic identification. Preferred linkers are amino acid sequences capable or prone to proteolytic breakdown. The cleavable linker of this invention is preferably located between the conformationally constrained reverse-turn mimetic and the ligand (such as biotin or the trypsin-like serine 15 protease Factor X).

A further cleavable linker of this invention contains a recognition site (i.e., cleavage site) for the aspartic protease cathepsin D. Other cleavable linkers of this 20 invention include, but are not limited to, the amino acid sequences which are cleavable by cathepsin B or by cathepsin E. Cathepsin B is a cysteine proteinase which cleaves sequences having a basic amino acid (such as arginine or lysine) at the P<sub>2</sub> and P<sub>3</sub> 25 positions, a small hydrophobic moiety at P<sub>1</sub>, and an aromatic hydrophobic moiety at P<sub>1'</sub> and P<sub>4</sub> (see Matsueda et al., *The Chemical Society of Japan - Chemistry Letters* pp. 1857-1860, 1988; Matsunaga et al., *FEBS* 324:325-330, 1993). Similarly, cathepsin E is an endosomal aspartic proteinase present in both B and T cells, but not in peritoneal 30 macrophages. The active cleft of this enzyme is capable of accommodating as many as nine residues, with a distinct preference for cleavage to occur between hydrophobic residues occupying the P<sub>1</sub>-P<sub>1'</sub> sites (e.g. Bennett et al., *Eur. J. Immunol.* 22:1519-1524, 1992).

Therefore, for the above described screening method, the mimetic includes both a 35 ligand (such as biotin for effective collection from the receptor), and a cleavable linkage (such as a peptide sequence susceptible to enzymatic cleavage). Such mimetics may be prepared by traditional chemistries that are complementary to and may be directly incorporated into the solid or liquid phase synthesis of the mimetics described above. To that end, the incorporation of biotin and cleavable linkages are preferably made on the C terminus of the mimetic. The mimetic may be schematically represented by the following representation:

N-terminus - reverse-turn mimetic - C terminus - cleavable link - ligand

The above mimetics may be synthesized by the same methods which yield 1  
5 reverse-turn mimetics themselves. Briefly, in order to incorporate a ligand such as biotin into the mimetic, a lysine residue is incorporated into the mimetic as the first residue. The nucleophilic epsilon amino group of the lysine side chain serves as the reactive site for the coupling of a ligand such as biotin. Treatment of the lysine residue with the reactive form of biotin such as the N-hydroxysuccinimide of biotin results in coupling 10 biotin to the mimetic. The peptide mimetic synthesis may then be continued by the addition of amino acid residues suitable to make up the cleavage site. For instance, mentioned above, the residue glycine, arginine, and glycine may be coupled to provide such a cleavable link. Once both the biotin and the cleavable link are in place, peptide mimetic synthesis follows as described above and in Examples 1-3.

In yet another aspect of the invention, methods for the identification of bioactive mimetics are disclosed. As described above, the bioactive mimetic may be released by treatment with a suitable enzyme. The result is a solution containing individual bioactive mimetics and the cleaving enzyme. The bioactive mimetics may be separated from the cleaving enzyme by traditional techniques such as size exclusion 15 filtration to provide a solution of bioactive mimetics suitable for analysis. In a preferred embodiment, the solution of bioactive mimetics is analyzed by the combination of liquid chromatography and mass spectrometry (LC-MS). When more than a single bioactive mimetic is collected from the screening assay of the mimetic library, liquid chromatographic analysis provides both a means for separation and quantification of the 20 bioactive mimetics. The chromatogram of such a mixture provides a binding profile for the mimetics. Elution of the liquid chromatogram into the mass spectrometer provides unambiguous identification of the bioactive mimetics.

The following examples are offered by way of illustration, not limitation.  
30

## EXAMPLES

### Example 1

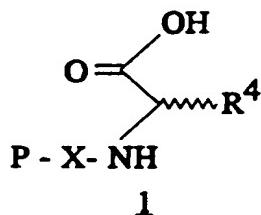
#### Synthesis of Component Pieces

This example presents the synthesis of the component pieces which combine to form the conformationally constrained reverse-turn mimetics of the present invention.

A. Synthesis of First Component Pieces

The first component piece of this invention has the following structure 1:

5



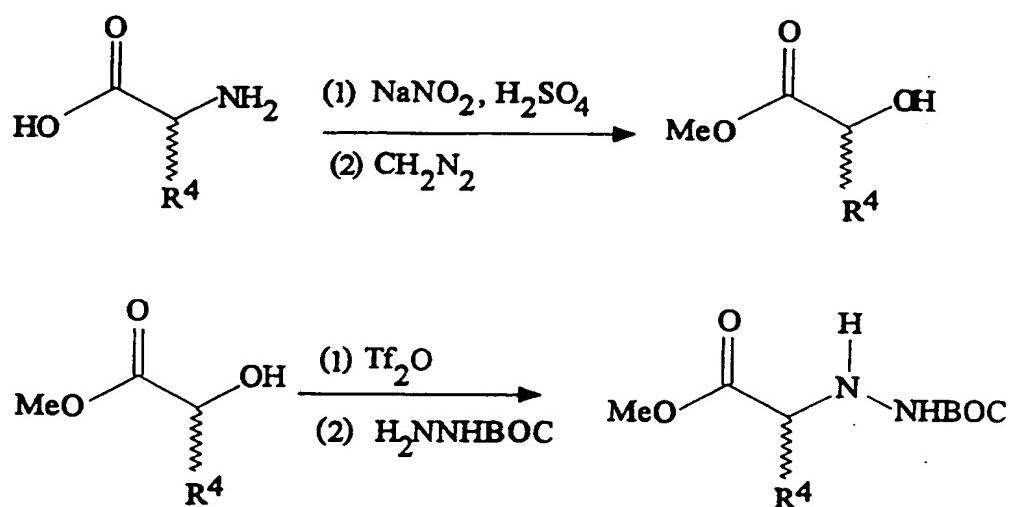
where  $\text{R}^4$  is an amino acid side chain moiety or derivative thereof, X is a chemical moiety selected from the moieties identified in Table 1, and P is an amino protective group suitable for use in peptide synthesis. The "X" moiety establishes the bridge between the first and third component pieces which defines the ring size of the conformationally constrained reverse-turn mimetic. The X moiety may be variable in length and flexibility, and thus effects the three-dimensional structure of the conformationally constrained reverse-turn mimetic.

The first component piece may be an N-protected hydrazine where the moiety X is a single nitrogen atom. Upon cyclization to the reverse turn mimetic, such a first component piece forms a hydrazide link with the carbonyl group of the third component piece. Alternatively, the first component piece may be an N-protected amine which upon cyclization forms an amide link. The synthesis of both general types of first compound pieces is set forth below.

(1) Synthesis of N-Protected Hydrazines (X=NH)

N-protected hydrazines for use as the first component piece may be made from their corresponding amino acids according to the procedures of Hoffman and Kim (*Tet. Lett.* 31:2953, 1990) and Vidal et al. (*J. Org. Chem.* 58:4791-4793, 1993). Briefly, an amino acid may be converted to the corresponding  $\alpha$ -hydroxy methyl ester by reaction with sodium nitrite in aqueous sulfuric acid followed by treatment with diazomethane. The  $\alpha$ -hydroxy group is displaced with mono-t-butyloxycarbonyl hydrazine after its conversion to trifluoromethanesulfonate with trifluoromethanesulfonic anhydride (with overall inversion of the amino acid configuration about the chiral carbon atom). The result is a first component N-protected hydrazine, a first component piece represented by formula 1 where the carboxylic acid group is protected as a methyl ester, X is NH, and P

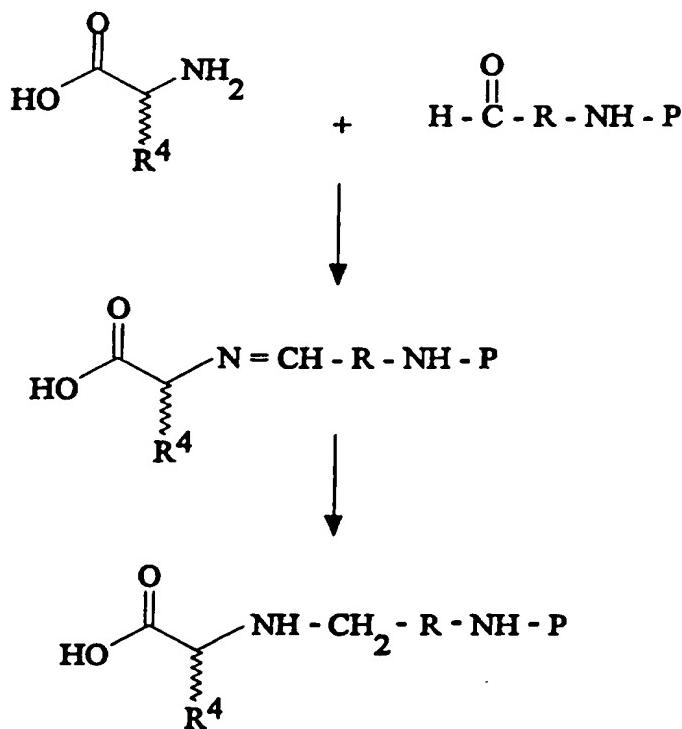
is the amino protective group, t-butyloxycarbonyl (BOC). The conversion of an amino acid to a representative first component N-protected hydrazine is shown below.



5

(2) Synthesis of First Component N-Protected Amines  
(X=NHRCH<sub>2</sub>)

Reductive amination. A variety of first component pieces may be prepared from suitable aldehydes by a facile reductive amination process, as described by Gribble and Nutatitis (*Org. Prep. Proced. Int.* 17:317, 1985) or Sasaki and Coy (*Peptides* 8:1 1987). In this method, reaction of the amino group of an amino acid with the carbonyl group of an aldehyde results in the formation of an imine which may be subsequently reduced with an appropriate hydride reducing agent to provide a C-N link. To produce such a first component piece of the present invention, the requisite aldehyde bears a protected amino group. The synthesis of first component N-protected amines by general method of reductive amination is presented schematically below (with overall retention of the amino acid configuration about the chiral carbon atom):

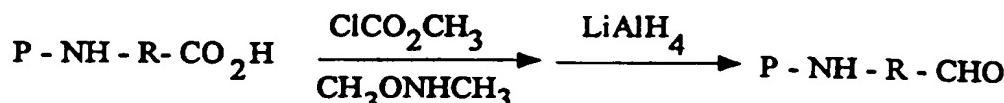


Alternatively, synthesis of the above N-protected amines may be accomplished on solid support by substituting the HOOC-CH(R<sup>4</sup>)-NH<sub>2</sub> moiety with P-OOC-CH(R<sup>4</sup>)-NH<sub>2</sub> to yield P-OOC-CH(R<sup>4</sup>)-NHCH<sub>2</sub>RNP.

The N-protected amino aldehyde shown above may be represented with the general formula, P-NH-R-CHO, where P is an amino protecting group and R is a chemical moiety (for example, -CH<sub>2</sub>-, -C(CH<sub>3</sub>)<sub>2</sub>-, -CH=CHC(CH<sub>3</sub>)<sub>2</sub>-, or -CH<sub>2</sub>CH<sub>2</sub>C(CH<sub>3</sub>)<sub>2</sub>-) which links the aldehyde carbonyl with the N-protected amino group. The product of the reductive amination shown above yields the first component piece of structure 1 when X is NH-R-CH<sub>2</sub>.

Synthesis of aldehydes from amino acids. The preparation of first component pieces with variable X by the reductive amination method requires the synthesis of suitable aldehydes, i.e., aldehydes which bear N-protected amino groups. Such suitable aldehydes may be directly prepared from their corresponding amino acids by a two step procedure as described by Goel et al. (*Org. Syn.* 67:69, 1988). In a typical reaction sequence, an N-protected amino acid is first converted to a mixed anhydride by treatment with methyl chloroformate and treatment with N,O-dimethylhydroxylamine provides the corresponding carboxamide, which is followed by reduction to the aldehyde with lithium aluminum hydride. The conversion of an N-protected amino acid to its

corresponding N-protected aldehyde, as described above, is illustrated schematically the following reaction:



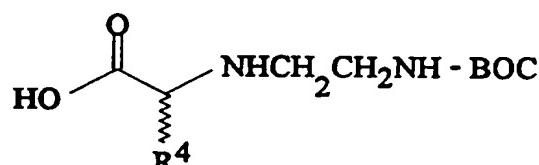
5

where P and R are as described above. The synthesis of suitable N-amino protected aldehydes is presented as sections (a)-(d) below.

(a) First Component N-Protected Amines (X=NHCH<sub>2</sub>CH<sub>2</sub>)

10 In this example, the aldehyde is an N-protected 2-aminoethanol and may prepared from its corresponding N-protected amino acid, glycine, according to process of Goel et al. as described in section (2) above. N-BOC-glycine is commercially available from a variety of sources and is suitable for conversion to its aldehyde, BOC-NH-CH<sub>2</sub>-CHO. Treatment of the resulting aldehyde, N-BOC-aminoacetaldehyde, with an amino acid under the reductive amination conditions as described in (2) above yields the first component N-protected amine shown below, which is the first component piece of general formula 1 when X is -NHCH<sub>2</sub>CH<sub>2</sub>- and P is the BOC protecting group:

15



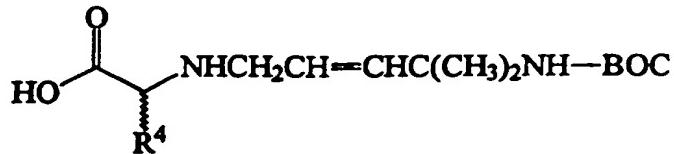
20

(b) First Component N-Protected Amines (X=NHC(CH3)2CH2)

In this example, the aldehyde is an N-protected 2-amino-2-methylpropanal, which may be prepared from its corresponding N-protected amino acid, 2-methylalanine, according to the process of Goel et al. as described in section (2) above. N-BOC-2-methylalanine is commercially available from a variety of sources and is suitable for conversion to its aldehyde, BOC-NH-C(CH<sub>3</sub>)<sub>2</sub>-CHO. Treatment of the resulting aldehyde, N-BOC-2-amino-2-methylpropanal, with an amino acid under the reductive amination conditions as described in section (2) above yields the first component N-protected amine shown below which satisfies the first component piece of general formula 1 where X is NHC(CH<sub>3</sub>)<sub>2</sub>CH<sub>2</sub>.

25

30



(c) First Component N-Protected Amines  
(X=NHC(CH<sub>3</sub>)<sub>2</sub>CH=CHCH<sub>2</sub>)

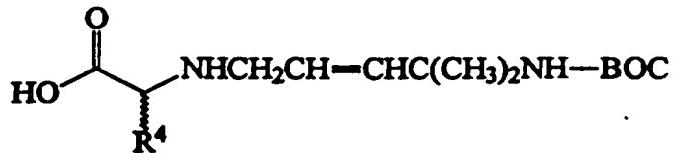
- 5 Extension of the length and adjustment of the flexibility of linker X may be achieved by homologation of the aldehydes described above. For example, the homologation of the aldehyde intermediate in section (2)(b) above by Wittig reaction provides a vinylogous analog as described in House and Rasmusson (*J. Org. Chem.* 26:4278, 1961).
- 10 Briefly, treatment of N-BOC-2-amino-2-methylpropanal, from section (2)(b) above, with methyl (triphenylphosphoranylidene) acetate results in the extension of the carbon chain of the aldehyde by two carbons. The reaction is represented schematically as follows.



- The ester product above may then be hydrolyzed under basic conditions to yield the corresponding N-BOC amino carboxylic acid, which may then be directly converted to the aldehyde by the reductive method of Goel et al. as described above in section (2).
- 20 Conversion of the carboxylic acid derived from the above ester to the corresponding aldehyde is illustrated below.



- 25 Treatment of the vinylogous aldehyde with an amino acid under the reductive amination conditions as described in section (2) above yields the first component N-protected amine shown below, which satisfies the first component piece general formula 1 when X is NHC(CH<sub>3</sub>)<sub>2</sub>CH=CHCH<sub>2</sub>:



(d) First Component N-Protected Amines  
(X=NHC(CH<sub>3</sub>)<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>)

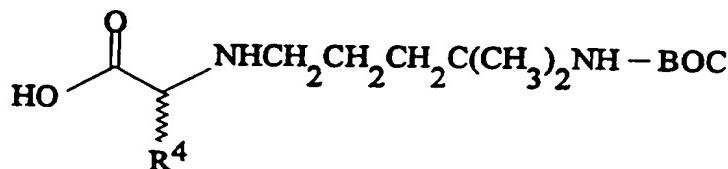
The X moiety of section (2)(c) above contains a vinyl group which imparts some rigidity to the linker moiety. A more flexible linker may be prepared by hydrogenation of the N-protected vinylogous aldehyde described above. Hydrogenation to the vinylogous aldehyde produces the saturated analog shown below.



10

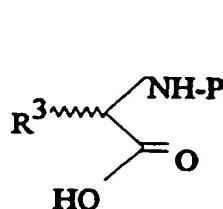
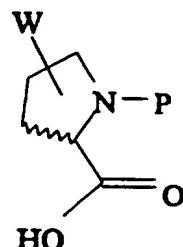
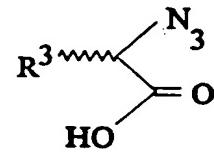
Treatment of the saturated aldehyde with an amino acid under the reductive amination conditions as described in section (2) above yields the first component protected amine shown below, which satisfies the first component piece general form 1 when X is NHC(CH<sub>3</sub>)<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>:

15



B. Synthesis of Second Component Pieces

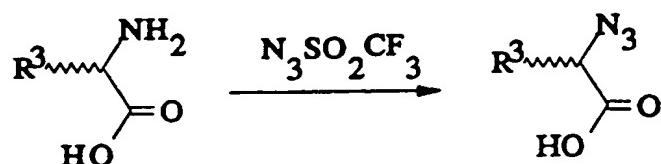
20                    The second component pieces of this invention may have any one of 1 following structures 2a, 2b or 2c:

2a2b2c

25                    where R<sup>3</sup> is an amino acid side chain moiety or derivative thereof, W is as defined previously, and P is an amino protective group suitable for use in peptide synthesis. Structure 2a is a generalized representation of an N-protected amino acid and structure 2b represents an N-protected proline derivative. Suitable second component pieces, 2a and 2b, are commercially available. For example, Fmoc amino acids are available from

a variety of sources. Alternatively, these or other N-protected amino acids may be readily prepared by standard organic synthetic techniques.

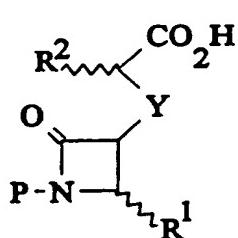
Second component piece 2c is an azido derivative of an amino acid. In this amino acid derivative, the  $\alpha$ -amino group has been substituted with an azido group. The 5 azido derivative of an amino acid may be prepared by the following reaction (Zaloom et al., *J. Org. Chem.* 46:5173-5176, 1981):



10

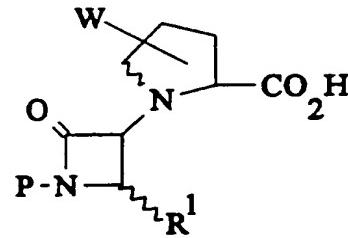
### C. Synthesis of Third Component Pieces

The third component piece may have any one of the following structures:

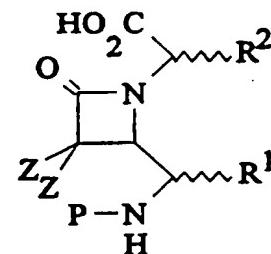


15

3(a)



3(b)

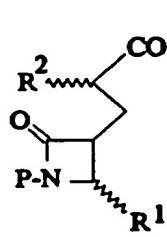


3(c)

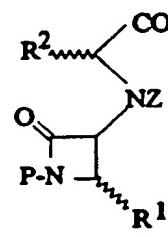
20

where R<sup>1</sup> and R<sup>2</sup> are an amino acid side chain moieties or derivatives thereof, Y is -CH<sub>2</sub>-, -NZ-, -O- or -S-, Z is H or -CH<sub>3</sub>, W is as defined previously, and P is an amino protective group suitable for use in peptide synthesis. Preferred protective groups include t-butyl dimethylsilyl (TBDMS), BOC, Fmoc and Alloc (i.e., allyloxycarbonyl).

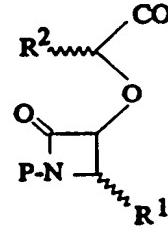
More specifically, third component piece 3(a) may have any one of the following structures:



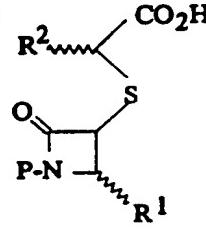
3(a1)



3(a2)



3(a3)

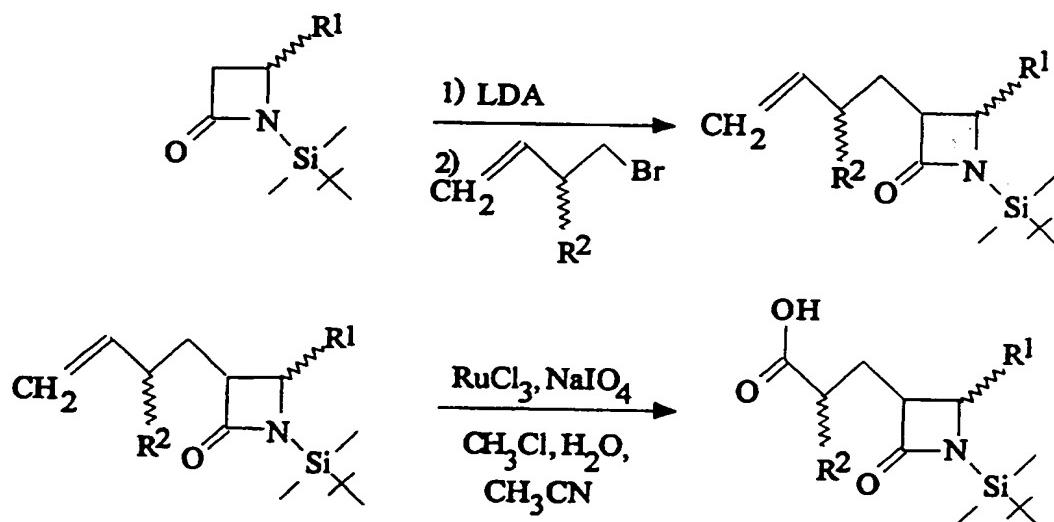


3(a4)

The third component pieces of the present invention are  $\beta$ -propiolactam derivatives, also commonly known as 2-azetidinone derivatives. Third component piece 3a are analogous azetidinones which differ in the nature of the atom connecting the azetidinone ring with the carboxylic acid portion of the molecule. The atom connecting the two portions of these third component pieces are C, N, O and S for 3(a1), 3(a2), 3(a3) and 3(a4), respectively. Third component piece 3b is a derivative of 3a wherein R<sup>2</sup> is proline. Third component piece 3c is a 2-substituted azetidinone in which the azetidinone nitrogen is also the  $\alpha$ -amino group of an  $\alpha$ -amino acid. Representative syntheses of these third component pieces 3a-3c follows.

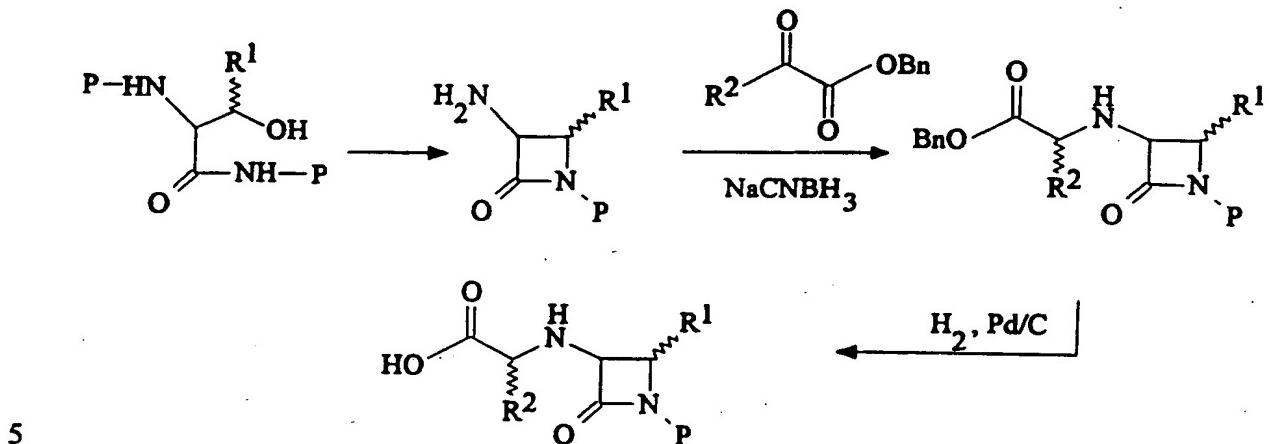
(1) Synthesis of Third Component Piece 3(a1)

Third component piece 3(a1) may be prepared by the method as generally described in Williams et al., *J. Amer. Chem. Soc.* 111:1073, 1989. The synthesis of 3(a1) is presented schematically below.



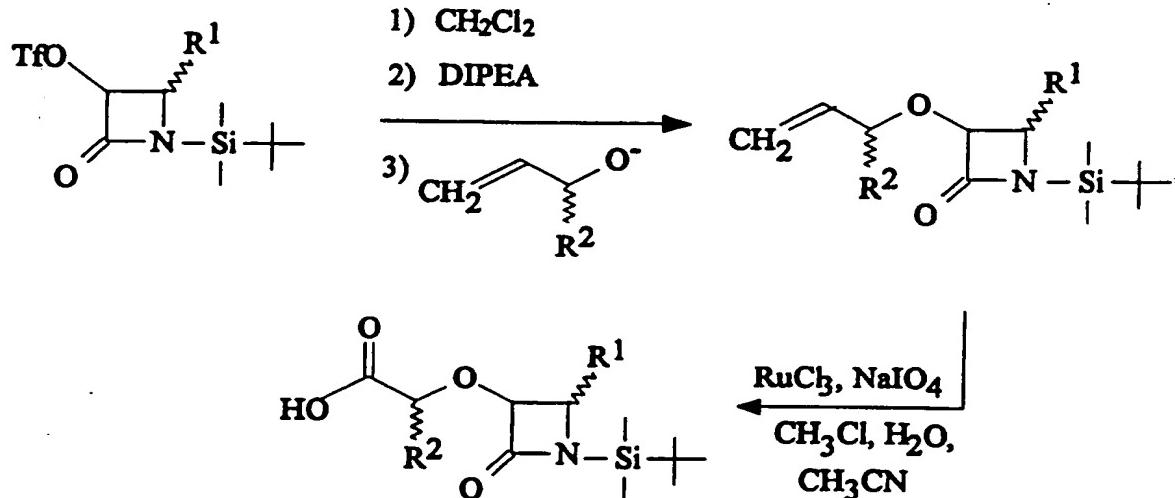
Briefly, the anion of an N-TBDMS-2-azetidinone generated by treatment with lithium diisopropylamide is alkylated with a 4-bromobutanyl derivative to yield the corresponding 4-butenyl azetidinone. Oxidative cleavage of the terminal alkene with ruthenium tetroxide provides third component piece 3(a1), where P is the TBDMS protective group.

Third component piece 3(a2) may be prepared by the method as generally described in Miller et al. (*J. Amer. Chem. Soc.* 102:7026, 1980). The synthesis of 3(a2) is presented schematically below.



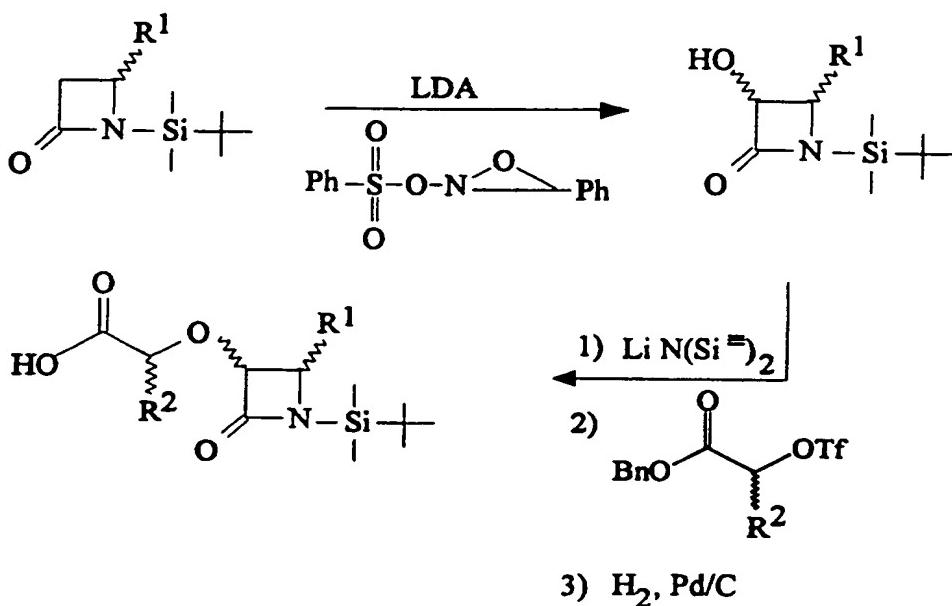
Briefly, the cyclization of a  $\beta$ -hydroxy amide derivative provides an 4-amino-2-azetidinone. Condensation of the azetidinone amino group with an  $\alpha$ -keto benzyl ester derivative, and concomitant reduction with sodium cyanoborohydride, yields an ester of 3(a2). Hydrogenolysis of the benzyl protecting group produces third component piece 3(a2).

(3) Synthesis of Third Component Piece 3(a3)  
 Third component piece 3(a3) may be prepared by the method as represented 15 schematically below:



Briefly, displacement of the trifluoromethane sulfonate group from a trifluoromethanesulfonyl-2-TBDMS-2-azetidinone derivative (from hydroxy azetidine by the oxyanion of an allyl alcohol provides a terminal alkene of 3(a3). Oxida  
5 cleavage of the terminal alkene with ruthenium tetroxide provides carboxylic acid 3(a1)

Alternatively, and in a preferred embodiment, the third component piece 3(a2) prepared by the following procedure:



10

In the above reaction, hydroxylation of the  $\beta$ -lactam and displacement of corresponding triflate of the hydroxy ester, and subsequent hydrogenolysis, provides the desired third component piece.

15

#### (4) Synthesis of Third Component Piece 3(a4)

Third modular component piece 3(a4) is made in the same manner as 3(a1) except  $\text{POC(O)CH(R}^2\text{)S}^-$  is added in place of the allyl alcohol, and the resulting ester hydrolysed to yield 3(a4).

20

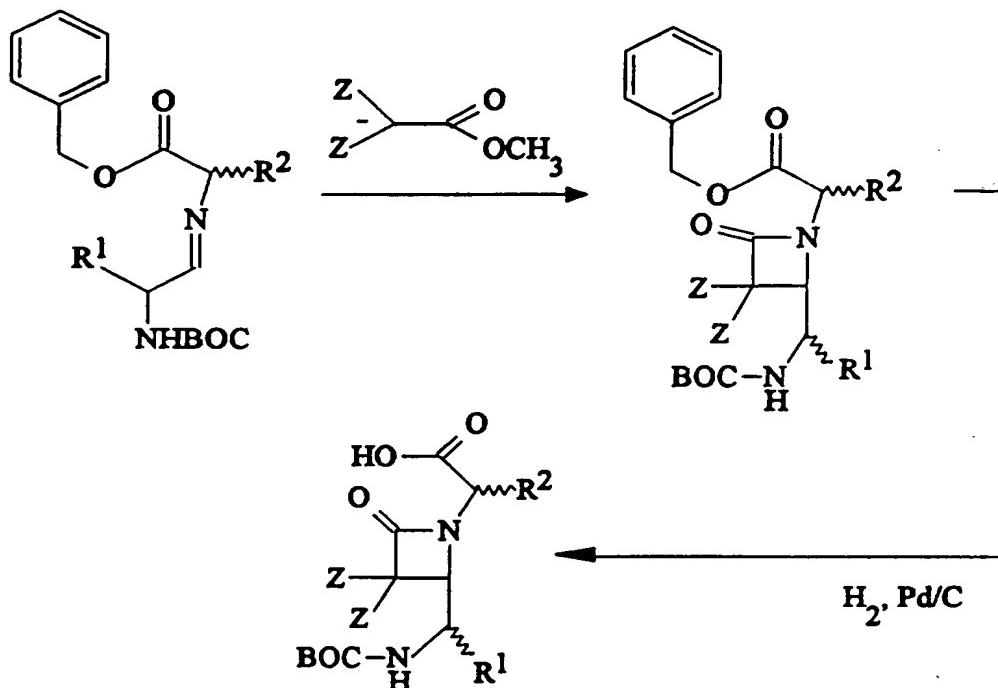
#### (5) Synthesis of Third Component Piece 3b

Third modular component piece 3b is made in the same manner as 3(a3), except an ester of proline is added in place of the allyl alcohol, and the resulting ester hydrolysed to yield 3(b).

(6) Synthesis of Third Component Piece 3c

Third component piece 3c may be prepared by the method as generally described in Hart and Hu (*Chem. Rev.* 89:1447, 1990). The synthesis of 3c is presented schematically below.

5



Briefly, the imine product of the condensation of the  $\alpha$ -amino group of a amino acid benzyl ester with the carbonyl group of an N-BOC protected aldehyde derived from an  $\alpha$ -amino acid was treated with the enolate of methyl isobutyrate to yield a 4,4-dimethyl-2-azetidinone derivative. Hydrogenolysis of the benzyl protecting group provides third component piece 3c where P is a BOC protecting group and Z is methyl.

Alternatively, treatment of the imine above with the enolate of methyl acetate followed by hydrogenolysis provides third component piece 3c where Z is hydrogen.

15

Example 2The Coupling of First, Second and/or Third Component Pieces

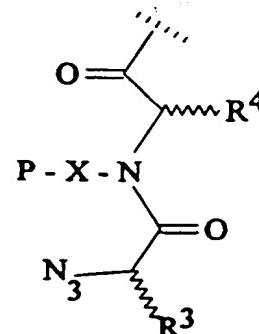
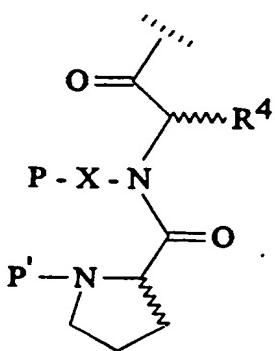
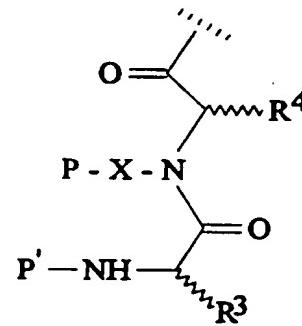
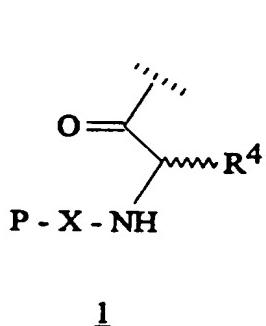
The coupling of the component pieces to produce the reverse-turn mimetics of the present invention generally involve the formation of amide bonds. The amide bonds which link the pieces may be formed by standard synthetic peptide techniques and may be performed by either liquid or solid phase synthesis.

Typically, in the solid phase synthesis of a peptide containing a conformationally constrained reverse-turn mimetic, the first component piece is incorporated into the peptide sequence at a specific point in the synthesis. Once the first component piece is incorporated, the synthesis of the remainder of the mimetic turn follows. For example, for a conformationally constrained beta-turn mimetic, the turn is synthesized by subsequent coupling of a second and a third component piece, followed by cyclization of the first component piece to the third component piece. The remainder of the peptide may then be synthesized by further elongation of the peptide chain via continued stepwise coupling of the remaining amino acids.

10

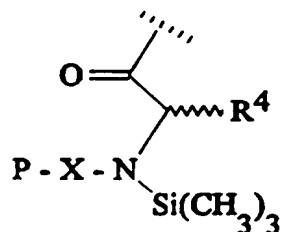
A. Representative Coupling of First and Second Component Pieces

The coupling of the first and second component pieces provides a combined first-second intermediate. Three different combined first-second intermediate species may be formed by coupling the first component piece 1 with second component pieces 2a, 2b or 2c. The coupling products, identified as 1-2a, 1-2b, and 1-2c, are shown below.



In the above representation, P is BOC and P' is FMOC.

The coupling of the first and second component pieces may be accomplished by a silicon mediated acid fluoride coupling. In this coupling procedure, solid phase immobilized **1** is converted to the corresponding N-trimethylsilyl derivative (**1a** below) 5 by treatment with 5 equivalents of bis(trimethylsilyl)acetamide.



**1a**

Reaction of either of the acid fluorides of **2a-2c** with N-silyl derivative **1a** yields 10 combined first-second intermediate **1-2a**, **1-2b**, or **1-2c**, respectively. The acid fluorides of **2a-2c** may be readily prepared from the corresponding carboxylic acids by cyanuric fluoride treatment according to general method as described by Carpino and Han (*J. Amer. Chem. Soc.* 112:9651-52, 1990).

15 (1) Peptide Coupling with N-FMOC Protected Amino Acids

The general silicon mediated acid fluoride peptide coupling procedure described above may be utilized to couple N-protected amino acid fluorides (such as **2a** or **2b**) with N-silyl peptides (such as **1a**). For peptide synthesis in the liquid phase, N-protected amino acid fluorides are coupled to carboxy protected N-silyl amino acids. The silicon 20 mediated acid fluoride coupling method represents an advancement over traditional amide forming reactions which employ coupling agents such as carbodiimides or mixed anhydride reagents. These reagents activate the carboxyl group of an amino acid for coupling with the amino group of another amino acid. Alternatively, and in a preferred embodiment, coupling between the amino terminus and carbonyl group can be effected 25 with HATU.

Despite the improvements and advantages that the silicon mediated acid fluoride coupling offers, in some instances, peptide bond formation remains difficult due to the steric interaction between the amino acid side chain of the N-silyl peptide and the traditional bulky N-FMOC (fluorenylmethoxycarbonyl) protecting group of the incoming 30 carboxy activated amino acid. In fact, reaction rates for the coupling of amino acids

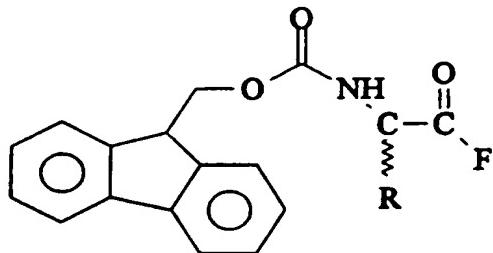
with relatively bulky side chains (such as histidine, phenylalanine, tryptophan, tyrosine, arginine, leucine, isoleucine, glutamine, asparagine, aspartic acid, glutamic acid, threonine) are significantly less compared with those amino acids having relatively sterically demanding side chains such as glycine, alanine, and serine in coupling reactions which utilize N-FMOC protected amino acids.

Peptide bond formation with secondary amines such as 1a is also more difficult for steric reasons. The additional amino substituent significantly increases the steric hindrance of the amine group and diminishes its nucleophilicity (ability to form peptide bond with a carboxy derivative). The diminution of reactivity is manifested in slow reaction rates. This difficulty in peptide coupling is especially true in reactions with FMOC protected amino acids.

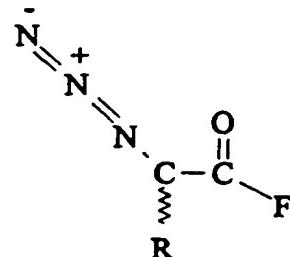
#### (2) Peptide Coupling with Azido Acid Fluorides

The steric problems associated with peptide coupling of bulky N-FMOC protected amino acid fluorides can be eliminated by the use of the corresponding azido acid fluorides. In contrast to the FMOC group, the azido group is a small (3 nitrogen atoms), linear substituent. The  $\alpha$ -amino group of an amino acid in the former fluorides are simply protected by a group (FMOC) which prevents interference in peptide coupling reaction. Once coupled, the protecting group is removed in subsequent couplings performed. In contrast, in azido acid fluorides, the  $\alpha$ -amino group of an amino acid has been transformed to an azido group ( $N_3$ ). After coupling with azido acid fluoride, the azido group may be directly activated for subsequent couplings. The overall result for either acid fluoride reagent is peptide bond formation. However, the azido acid fluoride reagent does not suffer from the problems of steric inhibition in peptide bond formation associated with N-FMOC protected amino acids.

Accordingly, azido acid fluorides are the reagents of choice for sterically demanding peptide bond formation. These couplings include reactions of amino acids with sterically bulky side chain moieties and amide bond formation with secondary amines. The structures of these acid fluorides is shown below (R represents an amino acid side chain moiety or derivative thereof).



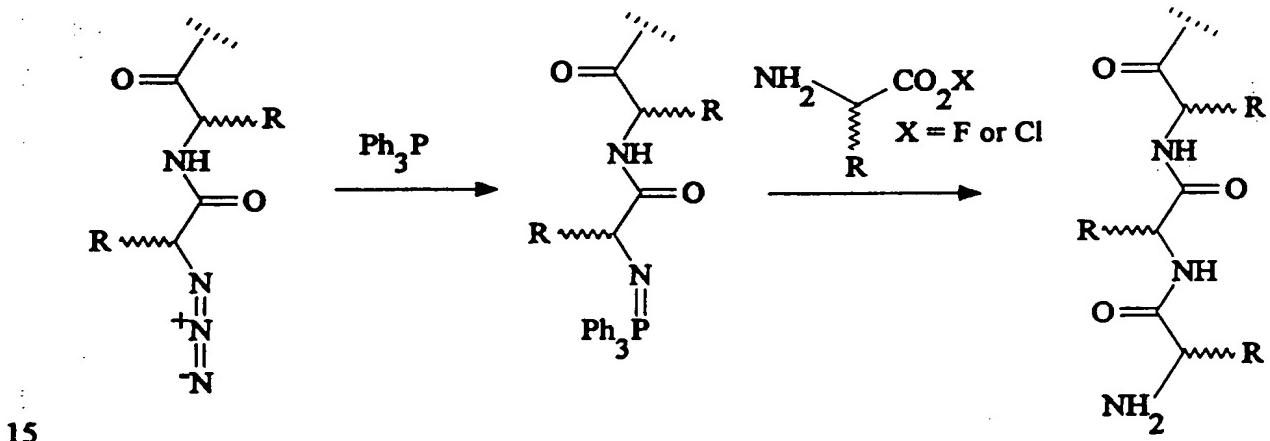
N-FMOC Protected Acid Fluoride



Azido Acid Fluoride

The azido acid fluorides may be prepared from their corresponding azido acids, and the 5 azido acids may be readily synthesized from the corresponding amino acids, by standard methods as disclosed above.

As mentioned above, unlike N-protected amino acid derivatives which must be deprotected prior to subsequent coupling, azido acids may be directly activated for peptide coupling with a subsequent amino acid. Treatment of the azido peptide with 10 triphenyl phosphine generates a phosphine imine which, upon reaction with an amino acid or a second or third component piece of the present invention yields a peptide bond and the corresponding chain lengthened peptide. The process is generally illustrated below where R is an amino acid side chain moiety:

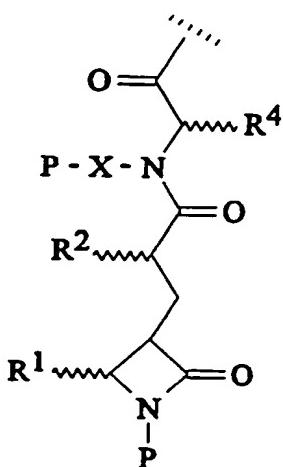
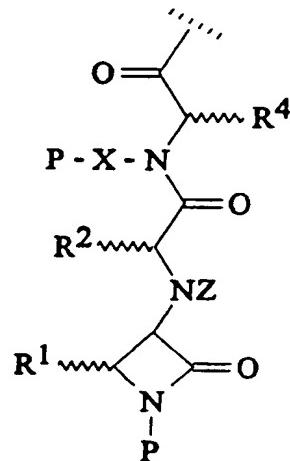
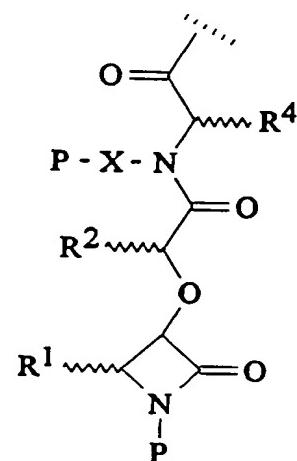
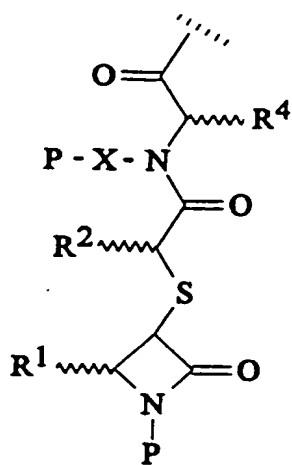


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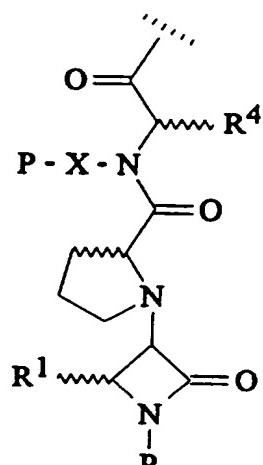
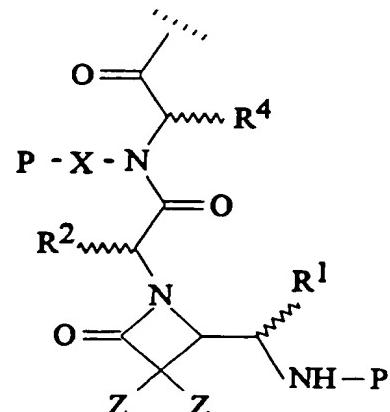
The azido acid fluoride peptide coupling method described above has utility in peptide coupling in general and, more specifically, in the practice of the present invention. This method is further illustrated for coupling of the modular component pieces of the present invention in sections C, D, and E below.

#### B. Representative Coupling of First and Third Component Pieces

The coupling of the first modular component and third modular components provides a combined first-third intermediate. Six different combined first-th intermediate species may be formed as result of the coupling of first component piece with either third component piece 3(a1), 3(a2), 3(a3), 3(a4), 3b, or 3c. The coupl products, identified as 1-3(a1), 1-3(a2), 1-3(a3), 1-3(a4), 1-3(b), and 1-3(c), are sho below:

1-3(a1)1-3(a2)1-3(a3)

10

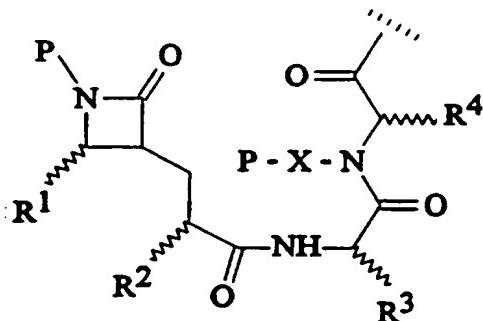
1-3(a4)1-3(b)1-3(c)

In the above representation, P is a protective group suitable for use in peptide synthesis, X is a linker as described in Example 1, and R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup> and R<sup>4</sup> represent an amino acid side chain moiety.

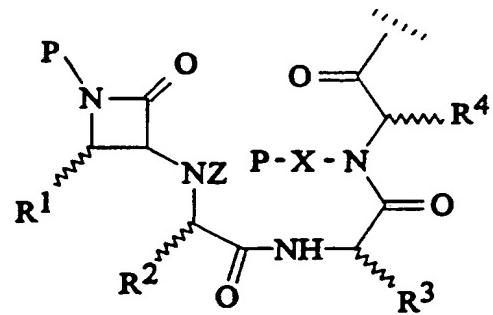
The coupling of the first and third component pieces is accomplished by the silicon mediated acid fluoride method as described in section A above via N-silyl derivative 1a. The combined first-third intermediates are precursors for conformationally constrained gamma-turn mimetic synthesis.

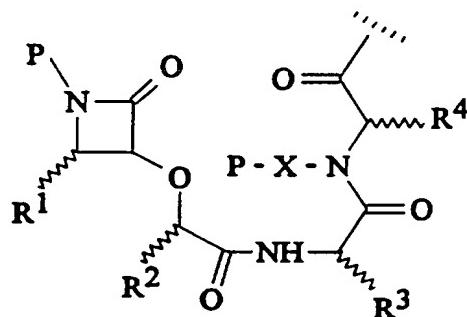
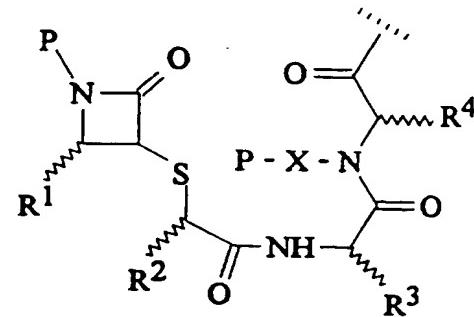
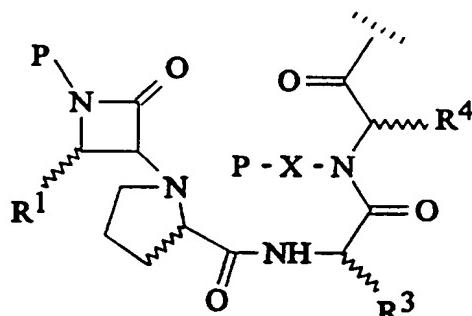
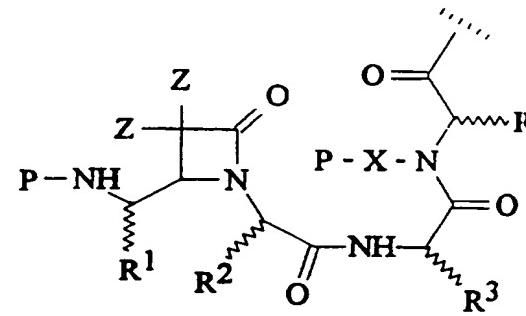
**C. Representative Coupling of a Combined First-Second Component Intermediate with a Third Component Piece**

The coupling of a combined first-second intermediate with a third modular component piece provides a combined first-second-third intermediate. Eighteen different combined first-second-third intermediate species may be formed as result of coupling each of the three first-second intermediates 1-2(a), 1-2(b), or 1-2(c) with each of the six third component pieces 3(a)-3(c). The products of coupling 1-2(a) with 3(a)-3(c), a representative set of first-second-third intermediate coupling products, identified as 1-2(a)-3(a1), 1-2(a)-3(a2), 1-2(a)-3(a3), 1-2(a)-3(a4), 1-2(a)-3(b), and 1-2(a)-3(c), are shown below:



20

1-2(a)-3(a1)1-2(a)-3(a2)

1-2(a)-3(a3)1-2(a)-3(a4)1-2(a)-3(b)1-2(a)-3(c)

5 In the above structures, P is a protective group suitable for use in peptide synthesis, X is a linker as described in Example 1, Z is either hydrogen or methyl, and R represents an amino acid side chain moiety. The remaining ten first-second-third intermediates, formed from coupling of 1-2(b) and 1-2(c) with 3(a)-3(c), would have structures analogous to those represented above.

10 For couplings involving 1-2(b) derivatives, the coupling of a combined first-second intermediate with a third component piece may be accomplished by traditional peptide coupling techniques such as those performed on automated peptide synthesizers. Briefly, the steps include N-deprotection of the combined first-second intermediate, addition and carboxyl group activation of the third component piece which results in peptide bond formation and coupling.

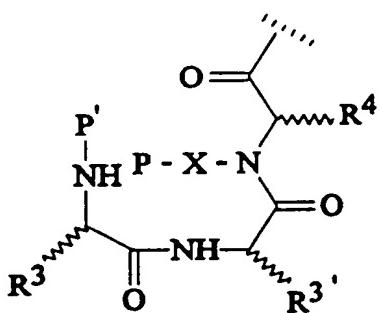
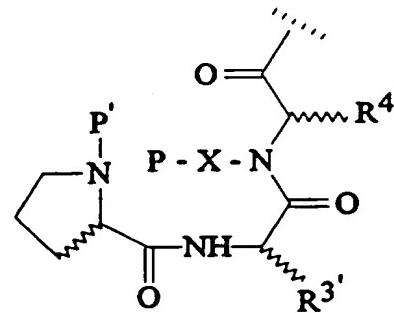
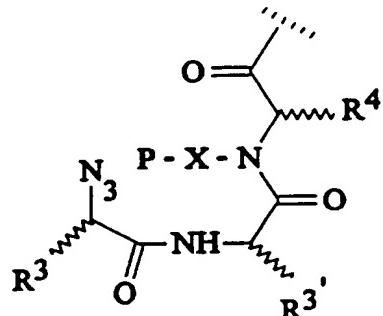
15 Alternatively, for couplings which involve 1-2(c) derivatives, the couplings are readily achieved via triphenyl phosphine activation as described above in section A(2).

The combined first-second-third intermediates are precursors required for conformationally constrained beta-turn mimetic synthesis.

D. Representative Coupling of a Combined First-Second Component Intermediate with a Second Component Piece

The coupling of a combined first-second intermediate with a second modular component piece provides a combined first-second-second intermediate. Nine different combined first-second-second intermediate species may be formed as result of the coupling each of the three first-second intermediates 1-2(a), 1-2(b), or 1-2(c) with each of the three second component pieces 2(a)-2(c). The products of coupling 1-2(a) with 2(a)-2(c), a representative set of first-second-second intermediate coupling products, identified as 1-2(a)-2(a), 1-2(a)-2(b), and 1-2(a)-2(c), are shown below:

10

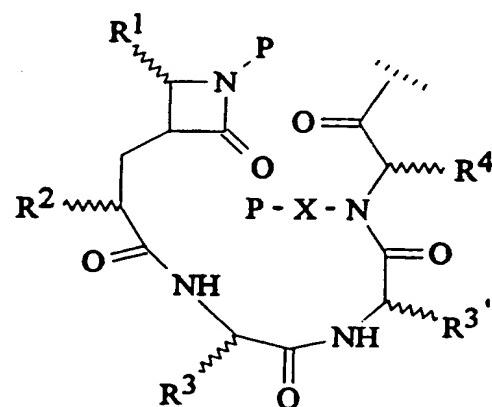
1-2(a)-2(a)1-2(a)-2(b)1-2(a)-2(c)

In the above representation, P is a protective group suitable for use in peptide synthesis, X is a linker as described in Example 1, and R represents an amino acid side chain moiety. The remaining first-second-second-third intermediates, formed from coupling of 1-2(b) and 1-2(c) with 2(a)-2(c), would have structures analogous to those represented above.

The coupling of a combined first-second intermediate with a second component piece may be accomplished by the peptide coupling techniques described in C above.

E. Representative Coupling of a Combined First-Second-Second Compon Intermediate with a Third Component Piece

The coupling of a combined first-second-second intermediate with a third modular component piece provides a combined first-second-second-third intermediate. Forty-five different combined first-second-second-third intermediate species may be formed as result of the coupling each of the nine first-second-second intermediates 2(a)-2(a), 1-2(a)-2(b), 1-2(a)-2(c), 1-2(b)-2(a), 1-2(b)-2(b), 1-2(b)-2(c), 1-2(c)-2(a), 2(c)-2(b), and 1-2(c)-2(c) with each of the five third component pieces 3(a)-3(c). The products of coupling 1-2(a)-2(a) with 3(a1), a representative species of first-second-third intermediate coupling products, identified as 1-2(a)-2(a)-3(a1), is shown below:



1-2(a)-2(a)-3(a1)

15

In the above representation, P is a protective group suitable for use in peptide synthesis, X is a linker as described in Example 1, and R represents an amino acid side chain moiety. The remaining first-second-second-third intermediates, would have structures analogous to those represented above.

20 The coupling of a combined first-second-second intermediate with a third component piece may be accomplished by the peptide coupling techniques described in C above.

The combined first-second-second-third intermediates are precursors required for conformationally constrained beta-bulge mimetic synthesis.

25

Example 3

Cyclization of Combined Component Pieces to  
Form Conformationally Constrained Reverse-Turn Mimetics

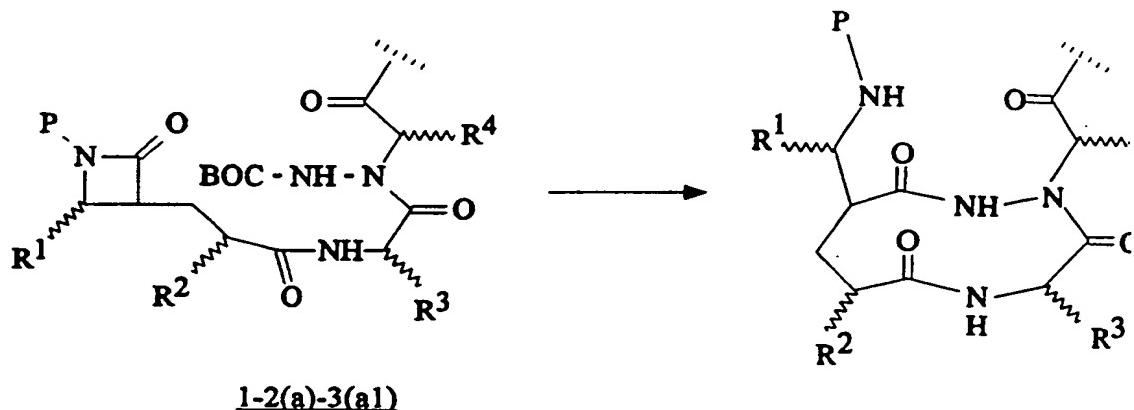
The cyclization of the first and third modular component pieces through covalent coupling of linking group X of the first component piece with the carbonyl carbon of the azetidinone group of the third component piece yields the conformationally constrained reverse-turn mimetics of the present invention. The presence of component pieces between the first and third component pieces determines the nature of the conformationally constrained reverse-turn mimetic (i.e., beta-turn, gamma-turn or beta-bulge mimetic).

Cyclization of the first component piece to the third component piece involves removal of protecting group P from linking group X of the first component piece. As described in Example 1A, P is an amino protective group, typically a BOC group. Therefore, treatment of the combined intermediate with TFA in CH<sub>2</sub>Cl<sub>2</sub> and subsequent neutralization with DIPEA removes the protecting group and provides linking group X, which bears a nucleophilic nitrogen. Depending upon the nature of X, the nucleophilic nitrogen is either a hydrazine, Example 1A(1), or an amine, Example 1A(2)(a-d).

The nucleophilic hydrazine or amine of the first component piece results in facile cyclization to the hydrazide or amide, respectively. The ease of cyclization is due to the proximity and the electrophilic nature of the azetidinone carbonyl of the third component piece.

**A. Representative Conformationally Constrained Beta-Turn: Cyclization of a Combined First-Second-Third Modular Component**

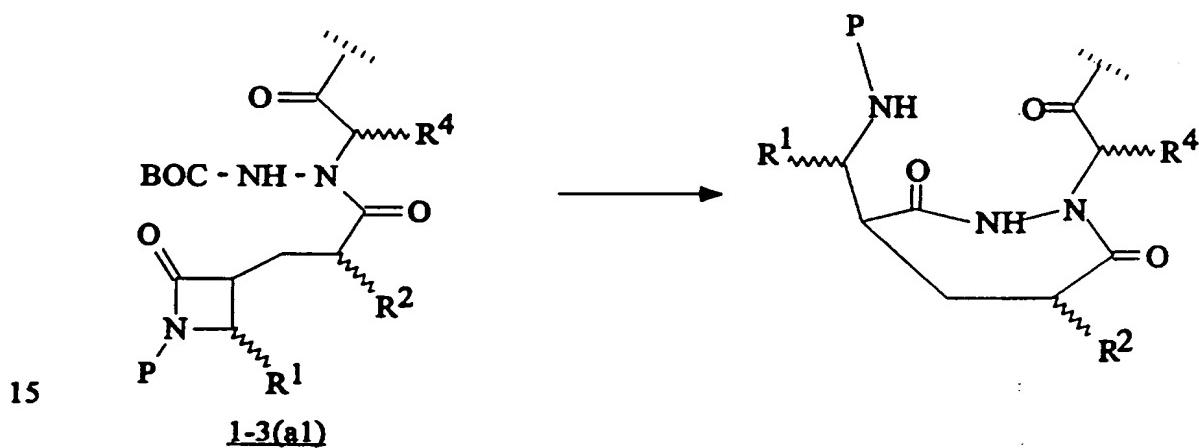
N-deprotection and cyclization of the first-second-third combined intermediate provides the beta-turn mimetic. The combined intermediate may be any one of those described above in Example 2C. For example, aqueous acid treatment of 1-2(a)-3(a1), for a species where X = -NH-, results in cyclization to the conformationally constrained beta-turn mimetic shown below:



The cyclization depicted above is representative for all beta-turn mimetic cyclization  
5 the present invention.

**B. Representative Conformationally Constrained Gamma-Turn Mimetic:  
Cyclization of a Combined First-Third Modular Component**

N-deprotection and cyclization of a first-third combined intermediate provides  
10 the gamma-turn mimetic. The combined intermediate may be any one of those described  
above in Example 2B. For example, aqueous acid treatment of 1-3(a1), for a species  
where X = -NH-, results in cyclization to the conformationally constrained gamma-turn  
mimetic shown below:

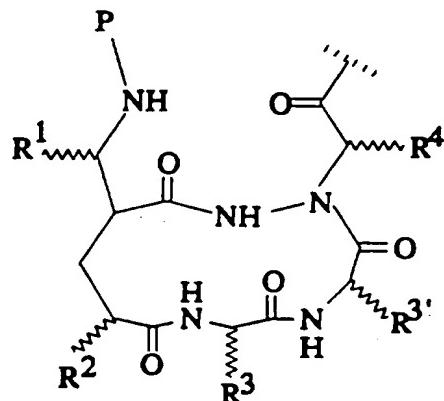
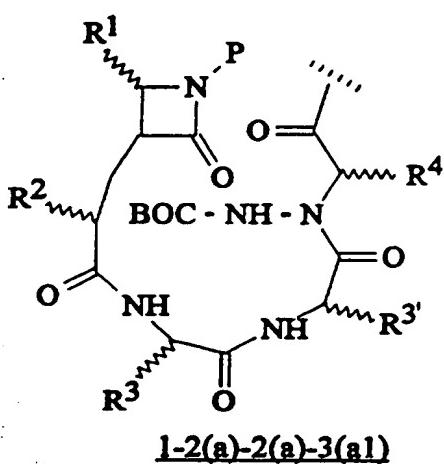


The cyclization depicted above is representative for all gamma-turn mimetic cyclization  
of the present invention.

C. Representative Conformationally Constrained Beta-Bulge Mimetic:  
Cyclization of a Combined First-Second-Second-Third Modular Component

N-deprotection and cyclization of a first-second-second-third combined intermediate provides the beta-bulge mimetic. The combined intermediate may be any one of those described above in Example 2E. For example, TFA/CH<sub>2</sub>Cl<sub>2</sub> treatment and neutralization of 1-2(a)-2(a)-3(a1), for a species where X = -NH-, results in cyclization to the conformationally constrained beta-bulge mimetic shown below.

10



The cyclization depicted above is representative for all beta-bulge mimetic cyclizations of the present invention.

15

Example 4

Synthesis of a Representative Library Containing  
Conformationally Constrained Reverse-Turns which Mimetic Beta-Endorphin  
and Identification of a Bioactive Mimetic Therefrom

20 In preferred embodiment of this invention, the sequence of a linear peptide having known biological activity is obtained. Such a sequences may be of a naturally occurring peptide, a sequence that was identified from a linear peptide library (e.g., synthetic or phage display), or a combination of epitopes that are part of a bioactive region of a protein. In this example, the linear peptide is beta-endorphin having the  
25 following sequence:

H-YGGFM TSEKS QTPLV TLFRN AIIKN AYKKG E-OH

The N-terminal sequence of the above peptide (*i.e.*, YGGFM(L)) is recognized by anti-beta-endorphin antibody, 3E7 (Boehringer Mannheim) (Lam et al., *Nature* 354: 84, 1991) (incorporated herein by reference).

5 A mimetic library is constructed around the N-terminal, pentapeptide sequence to determine its bound (*i.e.*, bioactive) conformation as follows:

Beta-Turn Mimetics:



Gamma-Turn Mimetics :



10 Beta-Bulge Mimetics:



Different X moieties are utilized (*e.g.*, -NH-, -NHCH(CH<sub>3</sub>)CH-

-NHC(CH<sub>3</sub>)<sub>2</sub>CH=CHCH<sub>2</sub>-, —NH——CH<sub>2</sub>—, and -NHC(CH<sub>3</sub>)<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>- resulting in beta-turn mimetics having 10-, 12- and 14-membered rings, gamma-turn mimetics having 7-, 9- and 11-membered rings, and beta-bulge mimetics having 13-, and 17-membered rings (*e.g.*, (2x5) + (3x5) + (1x5) = 30 members).

15 Synthesis of the above mimetics is generally achieved by the procedures disclosed in Examples 1-3 above, and illustrated in Figures 1 and 2. In Figures 1A and 1B, synthesis of the beta-turn mimetics having 12- and 14-membered rings are disclosed while Figures 2A, 2B and 2C illustrate synthesis of the gamma-turn mimetic having a 10-membered ring and a beta-turn mimetic having a 10-membered ring are disclosed. Synthesis of gamma-turns having 9- and 11-membered rings, and beta-bulges having 13- and 17-membered rings follows the synthesis illustrated in Figures 1A and 1B, except for the omission of the second component piece (gamma-turns) or addition of a further second component piece (beta-bulges). Synthesis of the beta-bulge containing a 13-membered ring follows the disclosure of Figures 2A, 2B and 2C, except a further seco-modular component piece is included.

20 More specifically, the first step involves coupling commercially available BO-Gly-PAM resin to the first two amino acids (*i.e.*, K and L) by DIC, HOBT (*i.e.* carbodiimide coupling) to yield FMOC-LKG-PAM. In the case of the beta-turn mimetics having 12- and 14-membered rings (and similarly for the gamma-turn mimetics having 9- and 11- membered rings and the beta-bulge mimetics having 15- and 17-membered rings), the next step is reductive amination on the resin to complete the

synthesis of the linker, X. In the case of the beta-turn mimetic having a 10-membered ring (and similarly for a gamma-turn mimetic having a 7-membered ring and a beta-bulge mimetic having a 13-membered ring), the amino acid hydrazide is presynthesized (i.e., the first component piece). Coupling of the second component piece to the hindered 5 secondary amine is effected using HATU (4x). Removal of the Fmoc group and coupling to the beta-lactam (i.e., the third component piece) is the same as outlined above in Example 2, and cyclizing the ring with TFA is accomplished by the methods disclosed in Example 3. A further amino acid may be added using HATU, with additional residues added via carbodiimide coupling. Cleavage of the reverse-turn 10 mimetics from the resin is effected by aminolysis (NH<sub>3</sub> in isopropanol).

The library members are then assayed in a standard ELISA format. Briefly, Costar ELISA strips (2588) are coated with 1 $\mu$ g/ml of beta-endorphin (Novabiochem) of carbonate buffer pH 8.6 at 50 $\mu$ g/well for 1 hour at room temperature, and then washed three times with PBS and 0.5% Tween 20. The wells are filled (about 350  $\mu$ l) 15 with blocking buffer (PBS, 1% BSA, and 0.05% Tween 20) and incubated at room temperature for 2 hours and washed three times.

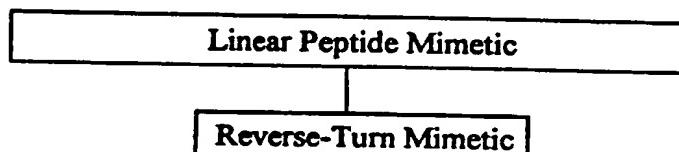
Anti-beta-endorphin antibody (3E7) is diluted to 150 ng/ml in blocking buffer, and the library members are incubated with 3E7 at varying concentration for 30 minutes at room temperature. Then 100  $\mu$ l of each mixture is applied to the wells and incubated 20 30 minutes to 1 hour at room temperature. The linear peptide YGGFLKG is tested similarly as a positive control. After 1 hour, the wells are washed three times and then incubated with Goat-anti-Mouse (Sigma) HRP conjugated antibody at 1:1000 dilution in blocking buffer (100  $\mu$ l/well) and incubated for 30 minutes to 1 hour at room temperature and washed three times. ABTS (Sigma) is dissolved at 1 $\mu$ g/ml in 0.1M 25 citrate buffer (pH 4.0) to which is added 10  $\mu$ l of 30% H<sub>2</sub>O<sub>2</sub> per ml of solution. 100  $\mu$ l of ABTS solution is added per well, incubated at room temperature for 30 minutes, and the optical density is read at 415 nM.

The most inhibitory reverse-turn mimetic is indicated by the well having the lowest optical density. Once having determined the reverse-turn mimetic template, the 30 above procedure is then repeated to yield a library containing reverse-turn mimetics having the same template, but having differing amino acid side chain moieties to determine the most biologically active. In other words, the side chains of the template are optimized by randomizing the amino acid residues, particular the residues of the ring. Further modification may also be made, such as modifying the amino terminus by, for 35 example, acylation, or by utilizing a mixture of D and L configurations, including an all D configuration.

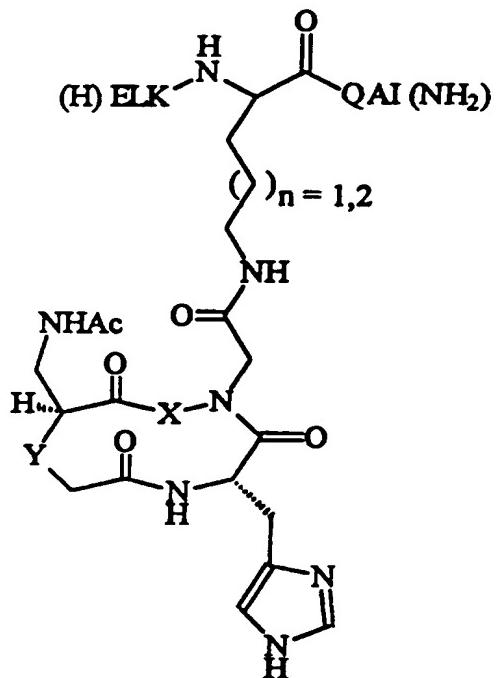
5

Example 5  
Synthesis of a Representative Library Containing  
Conformationally Constrained Reverse-Turns which Mimetic IL-8  
and Identification of a Bioactive Mimetic Therefrom

- IL-8 is a member of the chemokine superfamily, and has been implicated in inflammation, angiogenesis and neutrophil chemotaxis. Based on structural (Baldwin et al., *Proc. Natl. Acad. Sci.* 88:502-505, 1991) and mutational analysis (Clark-Lewis et al., *J. Biol. Chem.* 269:16075-16081, 1994) the region of IL-8 involved in binding to receptor is believed to encompass both the N-terminal residues 4-10 (ELRCQCI) & the loop containing Cys-34 (GPHC). In other words, the IL-8 binding region is believed to involve a linear peptide sequence closely associated with, in three-dimensional space, a reverse-turn structure.
- 15 To mimic this binding region, a reverse-turn of the present invention is joined to a linear peptide as represented by the following:



- 20 In the above representation, the linear peptide (or mimetic thereof) is covalently joined to one end of a reverse turn mimetic of this invention. In the case of IL-8, a library containing the following structures are synthesized:



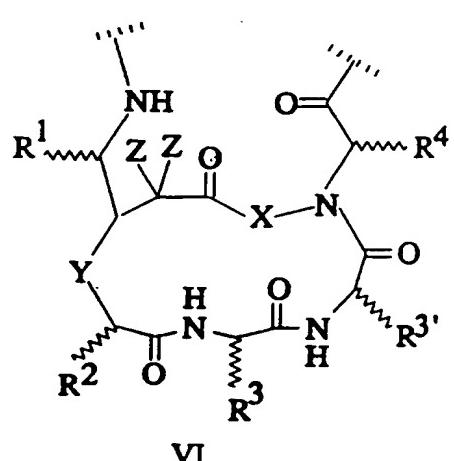
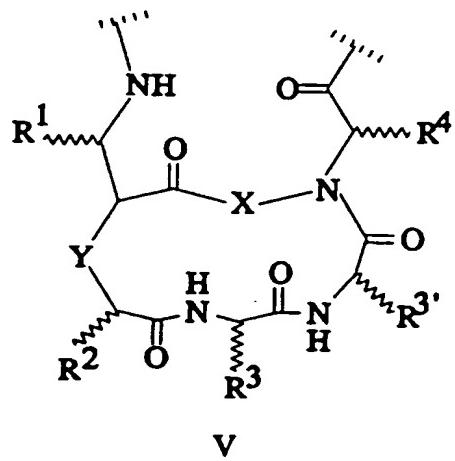
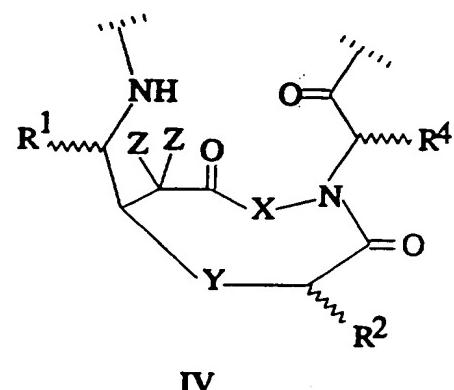
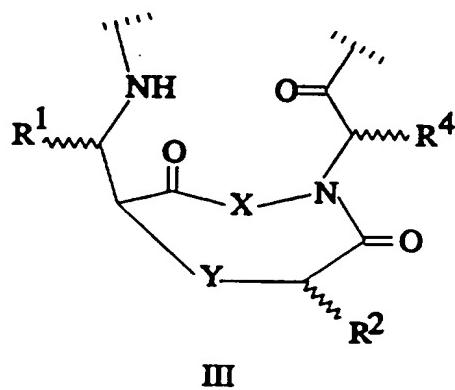
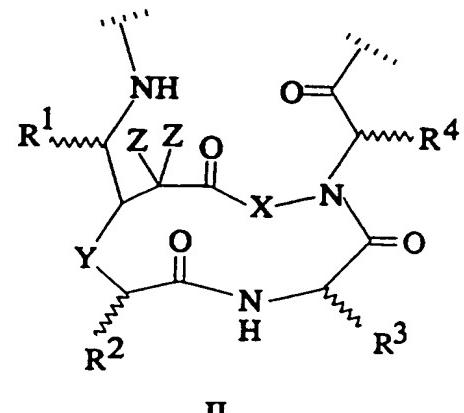
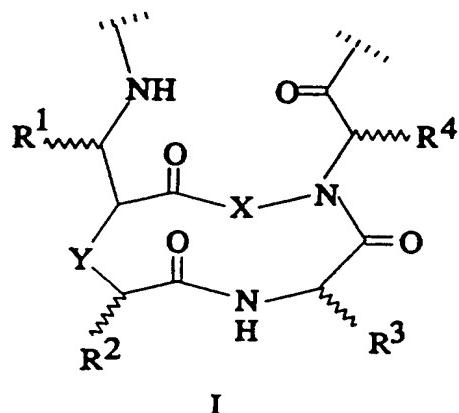
A library of the above mimetics is constructed in the manner disclosed above in Examples 1-4, with the exception of the linear peptide joined to the carbonyl terminus of the reverse-turn. In short, the peptide IAQ is constructed on PAM resin to yield PAM-IAQ-FMOC. A DDE ( $\epsilon$ -amino FMOC) lysine residue (Bycroft et al., *J. Amer. Chem. Soc.* 116:7415-7416, 1994) is then coupled thereto. The FMOC group is removed with diethylamine and the synthesis of the reverse-turn proceeds as disclosed by the previous examples. Subsequently, the DDE group is removed with 2%  $N_2H_4$  at room temperature, and the KLE residues are individually added using carbodiimide coupling. Cleavage from the resin is effected as described above.

The resulting library is screened by determination of the inhibition of IL-8 included elastase release from human neutrophils which have been pretreated with cytochalasin B. Such an assay is disclosed in Peveri et al., *J. Exp. Med.* 167:1547-1557, 1988 (incorporated herein by reference). The library may also be screened by other procedures, including the assay disclosed in Graminski and Lerner, *Biotechnology* 12:1008-1011, 1994 (incorporated herein by reference).

From the foregoing, it will be appreciated that, although specific embodiments of this invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except by the appended claims.

Claims

1. A library containing a plurality of conformationally-constrained revert mimetics as members, wherein the mimetics are selected from the following structures II, III, IV, V and VI:



wherein R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>3'</sup> and R<sup>4</sup> are amino acid side chain moieties, X is selected from the chemical moieties identified in Table 1, Y is selected from -CH<sub>2</sub>-, -N(Z)-, -O- and -S-, and Z is -H or -CH<sub>3</sub>.

2. A method for identifying a biologically active agent, comprising screening the library members of claim 1 in a suitable assay and thereby identifying the biologically active library member.

3. A method for identifying a biologically active conformationally constrained reverse-turn mimetic which mimics a biologically active conformation of a linear peptide having a known amino acid sequence, comprising:

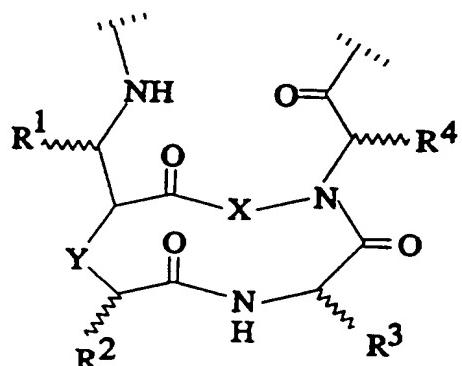
constructing conformationally constrained reverse-turn mimetics based on the known amino acid sequence of the linear peptide to yield a template library, wherein the template library contains a plurality of members selected from the group consisting of conformationally constrained beta-turn, gamma-turn and beta-bulge mimetics having multiple ring sizes;

screening the template library members in a suitable assay to identify a biologically active member of the template library;

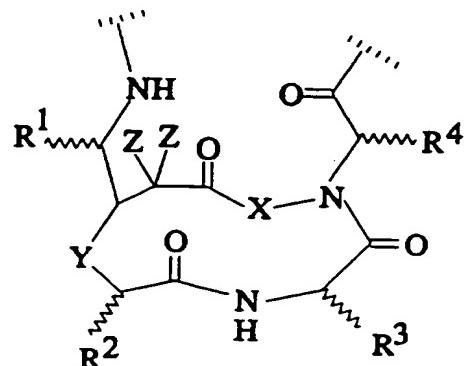
constructing conformationally constrained reverse-turn mimetics based on the biologically active member of the template library to yield an optimized library, wherein the optimized library contains a plurality of members having varying amino acid substitutions based on the known amino acid sequence of the biologically active linear peptide; and

screening the optimized library members in a suitable assay to identify a biologically active member of the optimized library.

4. A conformationally constrained reverse-turn mimetic having following structure I or II:



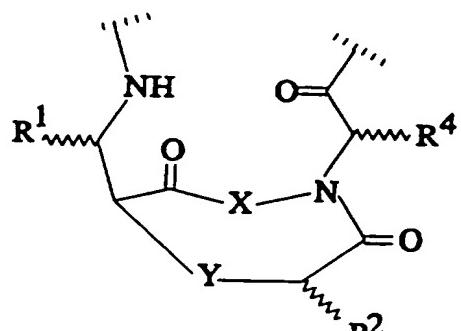
I



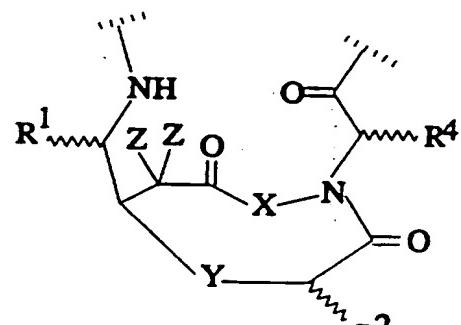
II

wherein  $R^1$ ,  $R^2$ ,  $R^3$  and  $R^4$  are amino acid side chain moieties,  $X$  is selected from the chemical moieties identified in Table 1, and  $Y$  is selected from -O- and -S-.

5. A conformationally constrained reverse-turn mimetic having following structure III or IV:



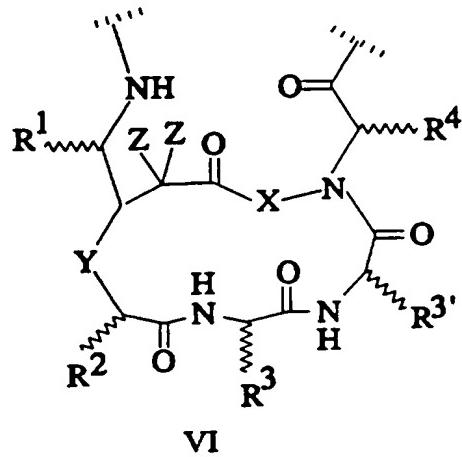
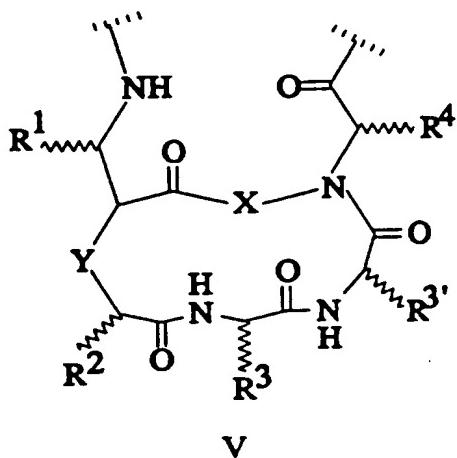
III



IV

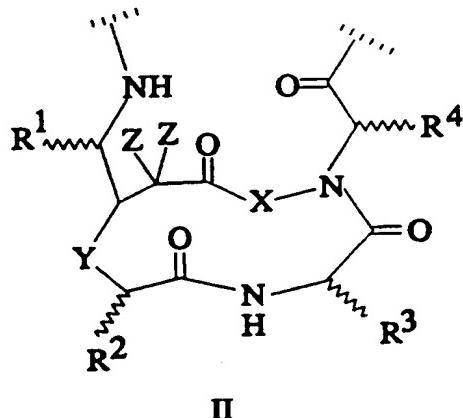
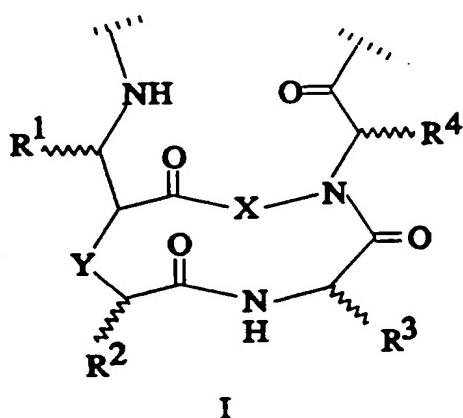
wherein  $R^1$ ,  $R^2$  and  $R^4$  are amino acid side chain moieties,  $X$  is selected from the chemical moieties identified in Table 1, and  $Y$  is selected from -O- and -S-.

6. A conformationally constrained reverse-turn mimetic having the following structure V or VI:

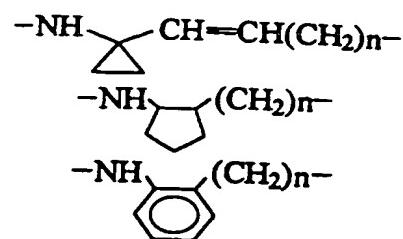
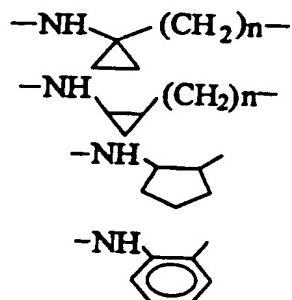


wherein  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^{3'}$  and  $R^4$  are amino acid side chain moieties,  $X$  is selected from the chemical moieties identified in Table 1, and  $Y$  is selected from -O- and -S-.

7. A conformationally constrained reverse-turn mimetic having the following structure I or II:

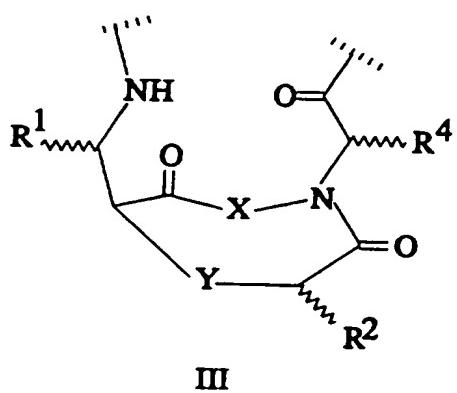


wherein  $R^1$ ,  $R^2$ ,  $R^3$  and  $R^4$  are amino acid side chain moieties,  $X$  is selected from

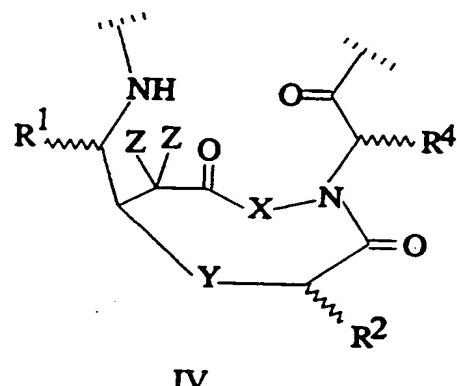


wherein n=1-4, and Y is selected from -CH<sub>2</sub>- and -NH-.

8. A conformationally constrained reverse-turn mimetic having the following structure III or IV:

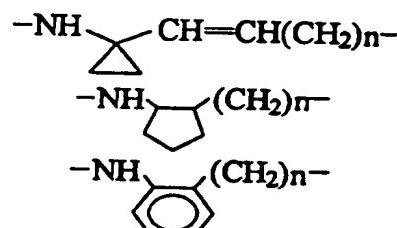
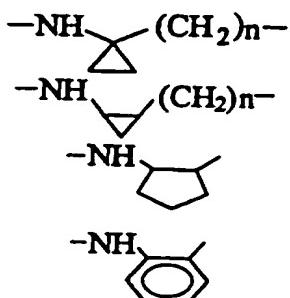


III



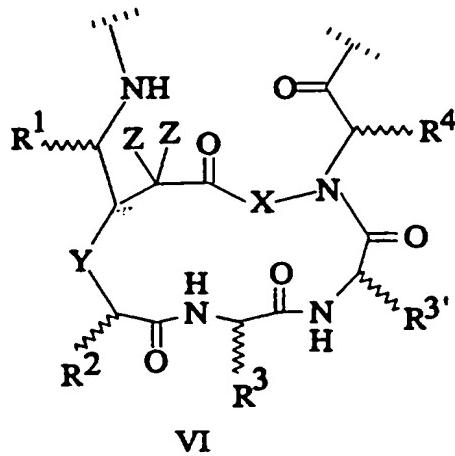
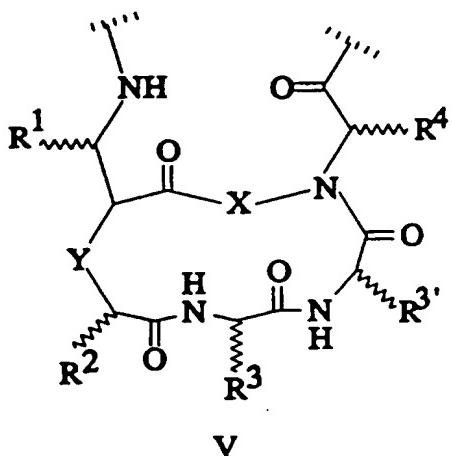
IV

wherein R<sup>1</sup>, R<sup>2</sup>, and R<sup>4</sup> are amino acid side chain moieties, X is selected from

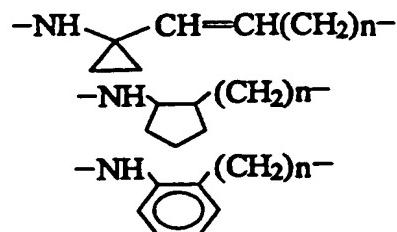
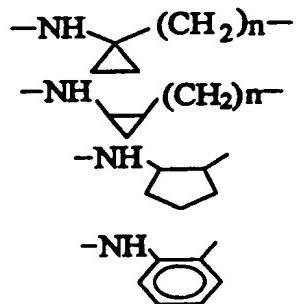


wherein n=1-4, and Y is selected from -CH<sub>2</sub>- and -NH-.

9. A conformationally constrained reverse-turn mimetic having the following structure V or VI:



wherein  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^{3'}$  and  $R^4$  are amino acid side chain moieties,  $X$  is selected from



wherein  $n=1-4$ , and  $Y$  is selected from  $-CH_2-$  and  $-NH-$ .

1/5

BOC — G — PAM

- ① TFA (deprotection)  
 ② DIC, HOBT, FMOC—Lys—OH  
 DDE

FMOC — KG — PAM

- ① Piperidine (deprotection)  
 ② DIC, HOBT, FMOC — Leu — OH

FMOC — LKG — PAM

- ① Piperidine (deprotection)  
 ② DIC, HOBT, FMOC — Phe — OH

FMOC — FLKG — PAM

- ① Piperidine (deprotection)  
 ② BOC—HN<sup>+</sup>—CH(CH<sub>2</sub>)<sub>3</sub>—CH<sub>2</sub>—C(=O)H      (or)      BOC—HN<sup>+</sup>—CH(CH<sub>2</sub>)<sub>2</sub>—C(=O)H  
 ③ Sodium cyanoborohydride, ACOH  
 ④ Neutralization with DIEA

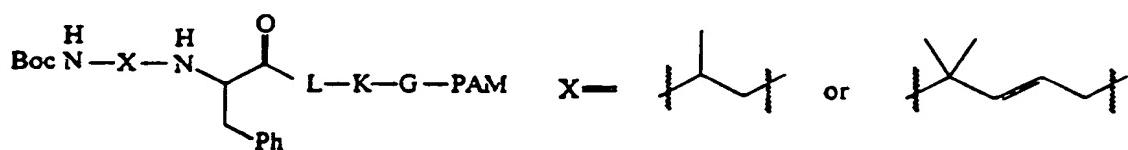
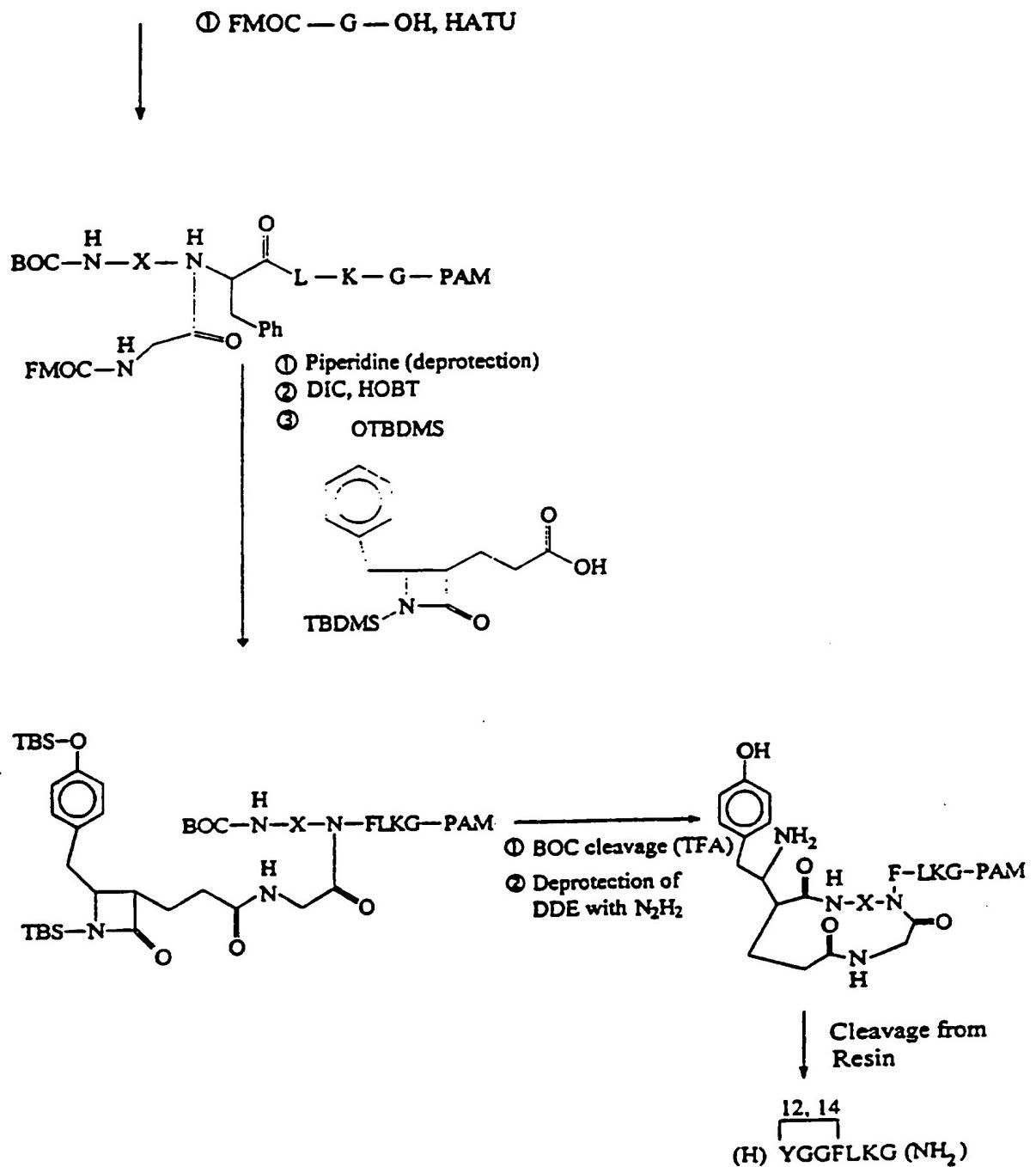


FIG. 1A

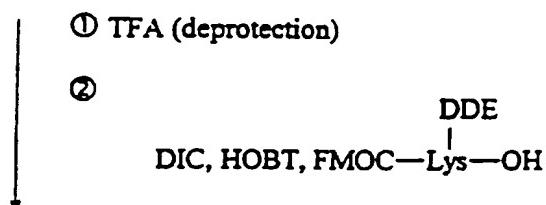
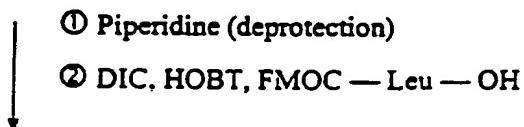
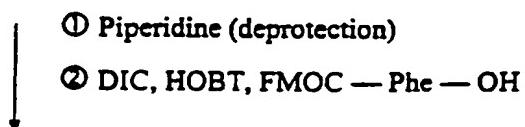
SUBSTITUTE SHEET (RULE 26)

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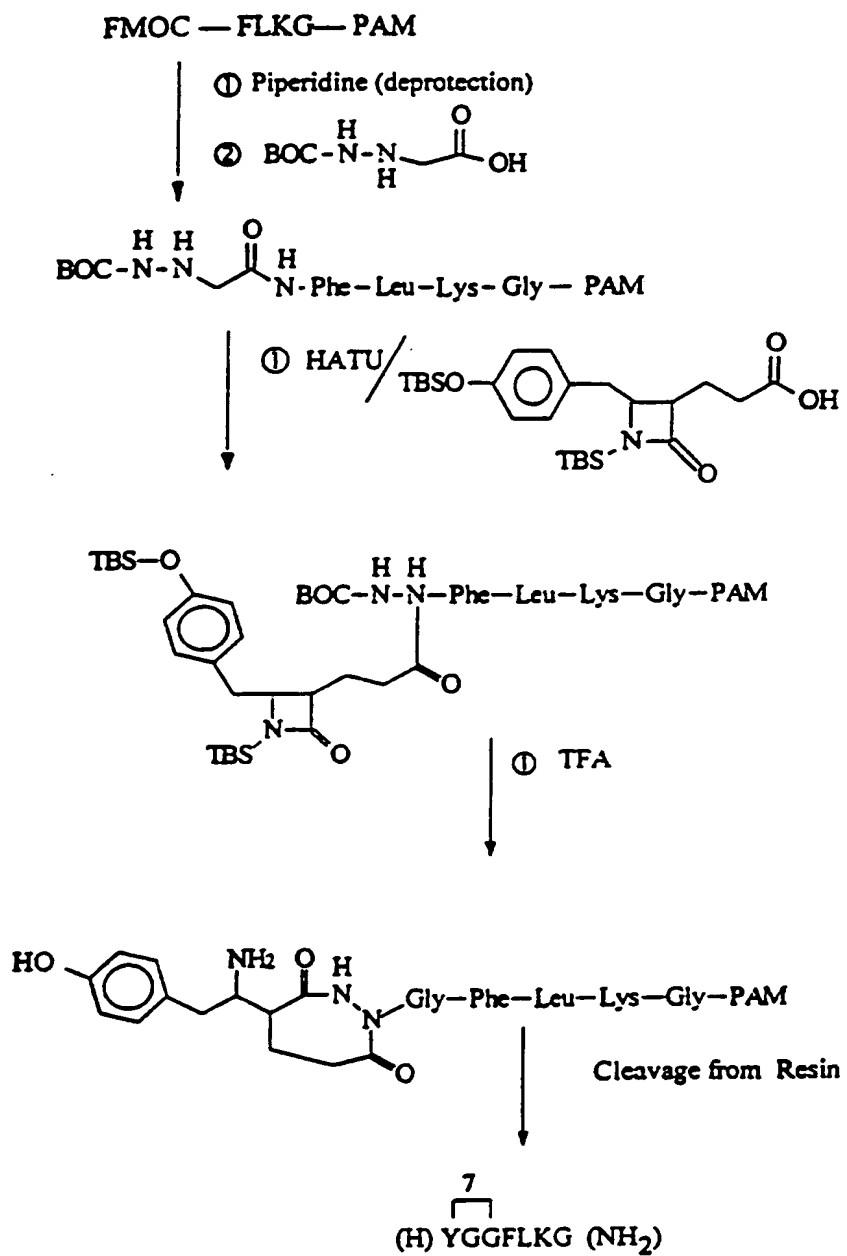


**FIG. 1B**  
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**BOC — G— PAM****FMOC — KG — PAM****FMOC — LKG — PAM****FMOC — FLKG — PAM****FIG. 2A**

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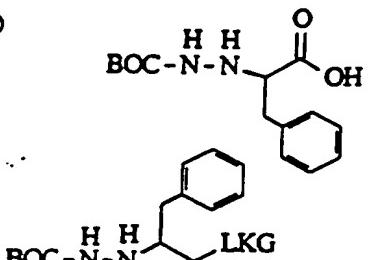
**FIG. 2B**

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FMOC — FLKG — PAM

① Piperidine (deprotection)

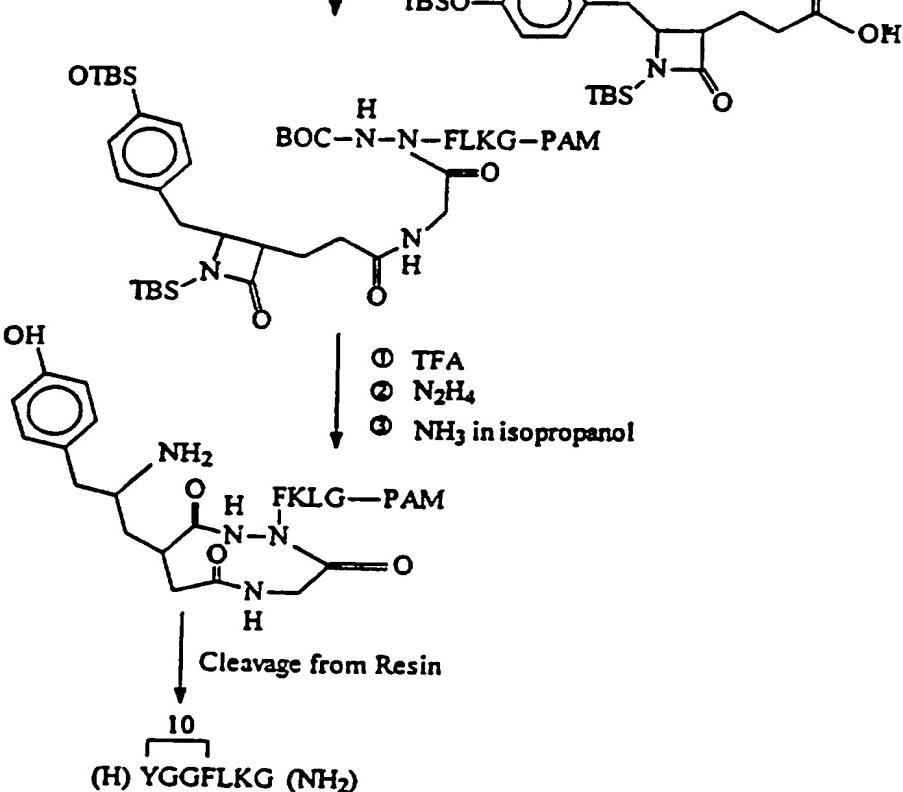
②



① HATU / FMOC-Gly

H H  
BOC-N-N-Phe-LKG-PAM

① (Piperidine) deprotection



**FIG. 2C**  
**SUBSTITUTE SHEET (RULE 26)**

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 96/00786

**A. CLASSIFICATION OF SUBJECT MATTER**  
**IPC 6 C07K1/04 C07K5/02**

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

**IPC 6 C07K**

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,92 13878 (UNIVERSITY OF ILLINOIS) 20 August 1992 see the whole document ---	4-9
X	WO,A,94 03494 (UNIVERSITY OF ILLINOIS) 17 February 1994 see the whole document ---	4-9
X	JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, vol. 116, no. 25, 14 January 1994, DC US, pages 11580-11581, XP002004648 A A VIRGILIO & J A ELLMANN: "Simultaneous solid-phase synthesis of beta-turn mimetics incorporating side-chain functionalities" see the whole document ---	1-3

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- \*A\* document member of the same patent family

Date of the actual completion of the international search

3 June 1996

Date of mailing of the international search report

18.06.96

## Name and mailing address of the ISA

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## Authorized officer

Masturzo, P

## INTERNATIONAL SEARCH REPORT

International Application No.  
PCT/US 96/00786

## C(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	WO,A,94 08051 (COLUMBIA UNIVERSITY & COLD SPRING HARBOR LABS.) 14 April 1994 see the whole document ---	1-3
P,X	CHEMICAL ABSTRACTS, vol. 123, no. 11, 11 September 1995 Columbus, Ohio, US; abstract no. 144616m, D K CHALMERS & G R MARSHALL: "Pro-D-NMe-Amino acid and D-Pro-NMe-Amino acid; simple, efficient reverse-turn constraints" page 1353; XP002004649 see abstract & JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, vol. 117, no. 22, 1995, DC US, pages 5927-5937, -----	1-3

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Int'l Application No  
PCT/US 96/00786

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